(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 July 2017 (13.07.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/120364 A1

(51) International Patent Classification:
A42B 3/12 (2006.01) *A42B 3/06* (2006.01)
A42B 3/00 (2006.01) *A42B 3/10* (2006.01)
A42B 3/04 (2006.01) *A63B 71/10* (2006.01)

(21) International Application Number:
PCT/US2017/012373

(22) International Filing Date:
5 January 2017 (05.01.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/276,793 8 January 2016 (08.01.2016) US

(71) Applicant: **VICIS, INC.** [US/US]; 570 Mercer Street, Seattle, WA 98109 (US).

(72) Inventors: **GLOVER, Travis, Edward**; c/o Vicis, Inc., 570 Mercer Street, Seattle, WA 98109 (US). **STONE, André Hunter, Paggao**; c/o Vicis, Inc., 570 Mercer Street, Seattle, WA 98109 (US). **FISCHER, Kurt, V.**; c/o Vicis, Inc., 570 Mercer Street, Seattle, WA 98109 (US). **FUKUDA, Kayla, Yukiko**; c/o Vicis, Inc., 570 Mercer Street, Seattle, WA 98109 (US). **ALFERNESS, Anton, Perry**; c/o Vicis, Inc., 570 Mercer Street, Seattle, WA 98109 (US). **LEONARD, Paul, C.**; c/o Vicis, Inc., 570 Mercer Street, Seattle, WA 98109 (US). **CZERSKI, Mike**; c/o Vicis, Inc., 570 Mercer Street, Seattle, WA 98109 (US). **ROGERS, Susan, Lucille**; c/o Vicis, Inc., 570 Mercer Street, Seattle, WA 98109 (US).

(74) Agents: **BRANNON, Brian** et al.; Fenwick & West LLP, 801 California Street, Mountain View, CA 94041 (US).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: IMPACT ABSORBING STRUCTURES FOR ATHLETIC HELMET

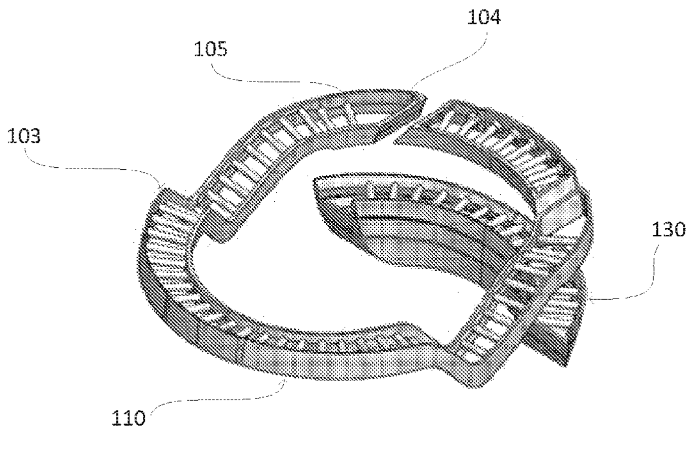

FIG. 2

(57) Abstract: A garment worn by a wearer has an exterior shell and an interior shell with impact absorbing material comprising various structures between the exterior shell and the interior shell. When force is applied to the exterior shell, the structures of the impact absorbing materials deform (e.g., compress), reducing the force received by the interior shell. For example, the impact absorbing material forms structures such as multiple branched "Y" shapes or multiple cylindrical rods with a surface contacting the exterior shell and a surface contacting the interior shell. The interior of the rods and other impact absorbing structures may be filled with a deformable material, such as foam. The impact absorbing material may be formed into jacks, spherical shapes, bristles, intersecting arches, or other shapes positioned between the exterior shell and the interior shell.

WO 2017/120364 A1

Published:

— *with international search report (Art. 21(3))*

IMPACT ABSORBING STRUCTURES FOR ATHLETIC HELMET

Cross-Reference to Related Applications

[0001] This application claims the benefit of U.S. Provisional Application No. 62/276,793, filed January 8, 2016, which is incorporated by reference in its entirety.

Background

[0002] A helmet protects a skull of the wearer from collisions with the ground, equipment, and other players. Present helmets were designed with the primary goal of preventing traumatic skull fractures and other blunt trauma. In general, a helmet includes a hard, rounded shell and cushioning inside the shell. When another object collides with the helmet, the rounded shape deflects at least some of the force tangentially while the hard shell distributes the normal force over a wider area of the head. Such helmets have been successful at preventing skull fractures but leave the wearer vulnerable to concussions.

[0003] A concussion occurs when the skull changes velocity rapidly relative to the enclosed brain and cerebrospinal fluid. The resulting collision between the brain and the skull results in a brain injury with neurological symptoms such as memory loss. Although the cerebrospinal fluid cushions the brain from small forces, the fluid does not absorb all the energy from collisions that arise in sports such as football, hockey, skiing, and biking. Helmets include cushioning to dissipate some of the energy absorbed by the hard shell, but the cushioning is insufficient to prevent concussions from violent collisions or from the cumulative effects of many lower velocity collisions.

Summary

[0004] In various embodiments, a helmet includes two generally concentric shells with impact absorbing structures between the shells. The inner shell may be somewhat rigid to protect against skull fracture and the outer shell may also somewhat rigid to spread impact forces over a wider area of the impact absorbing structures positioned inside the outer shell, or the outer shell may be more flexible such that impact forces locally deform the outer shell to transmit forces to a smaller, more localized section of the impact absorbing structures positioned inside the outer shell. The impact absorbing structures are secured between the generally concentric shells and have sufficient strength to resist forces from mild collisions. However, the impact absorbing structures undergo deformation (e.g., buckling) when subjected to forces from a sufficiently strong impact force. As a result of the deformation,

the impact absorbing structures reduce energy transmitted from the outer shell to the inner shell, thereby reducing forces on the wearer's skull and brain. The impact absorbing structures may also allow the outer shell to move independently of the inner shell in a variety of planes or directions. Thus, impact absorbing structures reduce the incidence and severity of concussions as a result of sports and other activities. When the outer and inner shell move independently from one another, rotational acceleration, which contributes to concussions, may also be reduced.

[0005] The impact absorbing structures may include impact absorbing members mechanically secured between the outer shell and the inner shell. In one example embodiment, an impact absorbing member comprises a column having one end secured to the inner shell and an opposite end secured to the outer shell. In another example, the impact absorbing member includes three portions joined at one point to form a branched shape. One of the portions is secured to the inner shell, and the other two portions are secured to the outer shell, or vice versa. By varying the length, width, and attachment angles of the impact absorbing members, the helmet manufacturer can control the threshold amount of force that results in deformation.

[0006] Alternatively, the impact absorbing structure may be secured to only one of the shells. When deformation occurs, the impact absorbing structure contacts an opposite shell or an impact absorbing structure secured to the opposite shell. Once the impact absorbing structure makes contact, the overall stiffness of the helmet increases, and the impact absorbing structure deforms to absorb energy. For example, ends of intersecting arches, bristles, or jacks are attached to the inner shell, the outer shell, or both.

[0007] The impact absorbing structures may also be packed between the inner and outer shells without necessarily being secured to either the inner shell or outer shell. The space between the impact absorbing structures may be filled with air or a cushioning material (e.g., foam) that further absorbs energy and prevents the impact absorbing structures from rattling if they are not secured to either shell. The packed arrangement of the impact absorbing structures simplifies manufacturing without reducing the overall effectiveness of the helmet.

[0008] The helmet may include modular rows to facilitate manufacturing. A modular row includes an inner surface, an outer surface, and impact absorbing structures between the inner and outer surfaces. A modular row is relatively thin and flat compared to the assembled helmet, which reduces the complexity of forming the impact absorbing structures between the modular row's inner and outer surfaces. For example, the modular rows may be formed by injection molding, fusible core injection molding, or a lost wax process, techniques which may not be feasible for molding the entire impact absorbing structures in its final form. When assembled, the inner surfaces of the modular rows may form part of the inner shell, and the outer surfaces of the modular rows may form part of the outer shell. Alternatively or additionally, the modular rows may be assembled between an innermost shell and an outermost shell that laterally secure the modular rows and radially contain them. Alternatively or additionally, adjacent rows may be laterally secured to each other.

Brief Description of the Drawings

[0009] FIG. 1 is a perspective view of an assembly of impact absorbing structures formed from modular rows, in accordance with an embodiment.

[0010] FIG. 2 is a perspective view of a modular row, in accordance with an embodiment.

[0011] FIG. 3 is a perspective view of a modular row, in accordance with an embodiment.

[0012] FIG. 4 is a plan view of an impact absorbing member having a branched shape, in accordance with an embodiment.

[0013] FIG. 5A is a perspective view of impact absorbing structures including intersecting arches, in accordance with an embodiment.

[0014] FIG. 5B is a perspective view of an opposing arrangement of the impact absorbing structures of FIG. 5A, in accordance with an embodiment.

[0015] FIG. 5C is a perspective view of impact absorbing structures including intersecting arches connected by a column, in accordance with an embodiment.

[0016] FIGS. 6A is a cross-sectional view of a helmet including impact absorbing structures having a spherical wireframe shape, in accordance with an embodiment.

[0017] FIG. 6B is a plan view of an impact absorbing structure included in the helmet of FIG. 6A, in accordance with an embodiment.

[0018] FIG. 6C is a perspective view of an impact absorbing structure included in the helmet of FIG. 6A, in accordance with an embodiment.

[0019] FIGS. 7A is a cross-sectional view of a helmet including impact absorbing structures having a jack shape, in accordance with an embodiment.

[0020] FIG. 7B is a plan view of an impact absorbing structure included in the helmet of FIG. 7A, in accordance with an embodiment.

[0021] FIG. 7C is a perspective view of an impact absorbing structure included in the helmet of FIG. 7A, in accordance with an embodiment.

[0022] FIGS. 8A is a cross-sectional view of a helmet including impact absorbing structures having a bristle shape, in accordance with an embodiment.

[0023] FIG. 8B is a cross-sectional view of an impact absorbing structure included in the helmet of FIG. 8A, in accordance with an embodiment.

[0024] FIG. 8C is a perspective view of an impact absorbing structure included in the helmet of FIG. 8A, in accordance with an embodiment.

[0025] FIG. 9 is a perspective view of an embodiment of an impact absorbing structure having a conical structure, in accordance with an embodiment.

[0026] FIG. 10 is a perspective view of an embodiment of an impact absorbing structure having a base portion and angled support portions, in accordance with an embodiment.

[0027] FIG. 11 is a perspective view of an embodiment of an impact absorbing structure having a cylindrical member coupled to multiple planar surfaces, in accordance with an embodiment.

[0028] FIG. 12 is a perspective view of an embodiment of an impact absorbing structure having a base portion to which multiple supplemental portions are coupled, in accordance with an embodiment.

[0029] FIG. 13A is a perspective view of an embodiment of a conical impact absorbing structure, in accordance with an embodiment.

[0030] FIG. 13B is a cross-sectional view of an alternative impact absorbing structure, in accordance with an embodiment.

[0031] FIG. 14 is a side view of an impact absorbing structure having arched structures, in accordance with an embodiment.

[0032] FIG. 15 is a perspective and cross-sectional view of an embodiment of an impact absorbing structure comprising a cylindrical structure enclosing a conical structure, in accordance with an embodiment.

[0033] FIG. 16 is a perspective view of an impact absorbing structure, in accordance with an embodiment.

[0034] FIGS. 17A-17C show perspective views of impact absorbing structures comprising connected support members, in accordance with an embodiment.

[0035] FIGS. 18-20 show example structural groups including multiple support members positioned relative to each other with different support members coupled to each other by connecting members, in accordance with an embodiment.

DETAILED DESCRIPTION

Modular Helmet

[0036] FIG. 1 is a perspective view of an assembly 100 of impact absorbing structures formed from modular rows 110, 120, and 130, in accordance with an embodiment. In general, a modular row includes an inner surface, an outer surface, and impact absorbing structures between the inner surface and the outer surface. The modular row may further include a protective layer (e.g., foam) less rigid than the impact absorbing structures that encloses a remaining volume between the inner surface and outer surface after formation of the impact absorbing structures. When a helmet including the assembly 100 is worn, the inner surface is closer to the user's skull than the outer surface. Optionally, the modular row includes end surfaces connecting the short edges of the inner surface to the short edges of the outer surface. The inner surface, outer surface, and end surfaces form a slice with two parallel flat sides and an arc or bow shape on two other opposing sides. The end surfaces may be parallel to each other or angled relative to each other. The modular rows include one or more base modular rows 110, crown modular rows 120, and rear modular rows 130. The assembly 100 may include further shells, such as an innermost shell, an outermost shell, or both, that secure the modular rows relative to each other and capture the structure between the innermost and outermost shells when assembled for durability and impact resistance.

[0037] The base modular row 110 encircles the wearer's skull at approximately the same vertical level as the user's brow. The crown modular rows 120 are stacked horizontally on top of the base modular row 110 so that the long edges of the inner and outer surfaces form parallel vertical planes. The end surfaces of the crown modular rows 120 rest on a top plane of the base modular row. The outer surfaces of the crown modular rows 120 converge with the outer surface of the base modular row 110 to form a rounded outer shell. Likewise, the inner surfaces of the crown modular rows 120 converge with the inner surface of the base modular row 110 to form a rounded inner shell. Thus, the crown modular rows 120 and base modular row 110 form concentric inner and outer shells protecting the wearer's upper head. The outer surface of a crown modular row 120 may form a ridge 122 raised relative to the rest of the outer surface. The ridge 122 may improve distribution of impact forces or facilitate a connection between two halves (e.g., left and right halves) of an outermost layer of a helmet including assembly 100.

[0038] The rear modular rows 130 are stacked vertically under a rear portion of the base modular row 110 so that the long edges of the inner and outer surfaces form parallel horizontal planes. The inner surface of the topmost rear modular row 130 forms a seam with the inner surface of the base modular row 110, and the outer surface of the topmost rear modular row 130 forms a seam with the outer surface of the base modular row 110. Thus, the rear modular rows 130 and the rear portion of the base modular row 110 form concentric inner and outer shells protecting the wearer's rear lower head and upper neck.

Modular Row

[0039] FIG. 2 is a perspective view of a base modular row 110, in accordance with an embodiment. The base modular row 110 includes two concentric surfaces 103 (e.g., an inner surface and an outer surface), end surfaces, and impact absorbing structures 105.

[0040] As illustrated, the impact absorbing structures 105 are columnar impact absorbing member is mechanically secured to both concentric surfaces 103. An end of the impact absorbing structure 105 may be mechanically secured to a concentric surface 103 as a result of integral formation, by a fastener, by an adhesive, by an interlocking end portion (e.g., a press fit), another technique, or a combination thereof. An end of the impact absorbing member is secured perpendicularly to the local plane of the concentric surface 103 in order to maximize resistance to normal force. However, one or more of the impact absorbing members may be secured at another angle to modify the resistance to normal force or to improve resistance to torque due to friction between an object and the outermost surface of a helmet including assembly100. The critical force that buckles the impact absorbing member increases with the diameter of the impact absorbing member and decreases with the length of the impact absorbing member.

[0041] Generally, an impact absorbing member has a circular cross section to eliminate stress concentration along edges, but other cross-sectional shapes (e.g., squares, hexagons) may be used to simplify manufacturing or modify performance characteristics. Generally, an impact absorbing structure is formed from a compliant, yet strong material such as an elastomeric substrate such as hard durometer plastic (e.g., polyurethane, silicone) and may include a core of a softer material such as open or closed-cell foam (e.g., polyurethane, polystyrene) or fluid (e.g., air). After forming the impact absorbing members, a remaining volume between the concentric surfaces 103 (that is not filled by the impact absorbing members) may be filled with a softer material such as foam or a fluid (e.g., air).

[0042] The concentric surfaces 103 are curved to form an overall rounded shape (e.g., spherical, ellipsoidal) when assembled into a helmet shape. The concentric surfaces 103 and end surfaces 104 may be formed from a material that has properties stiffer than the impact absorbing members such as hard plastic, foam, metal, or a combination thereof, or formed from the same material as the impact absorbing members. To facilitate manufacturing of the base modular row 110, a living hinge technique may be used. The base modular row 110 may be manufactured as an initially flat modular row, where the long edges of the concentric surfaces 103 form two parallel planes. For example, the base modular row 110 is formed by injection molding the concentric surfaces 103, the end surfaces 104, and the impact absorbing structures 105. The base modular row 110 may then be bent to form a living hinge. The living hinge may be created by injection molding a thin section of plastic between adjacent structures. The plastic is injected into the mold such that the plastic fills the mold by crossing the hinge in a direction transverse to the axis of the hinge, thereby forming polymer strands perpendicular to the hinge, thereby creating a hinge that is robust to cracking or degradation.

[0043] FIG. 3 is a perspective view of a modular row 110, in accordance with an embodiment. The modular row 110 has a beveled edge with a cross-section that tapers from a base to an edge along which the impact absorbing members 305 are secured. For example, the modular row 110 has a pentagonal cross section where the impact absorbing members 305 are mechanically secured along an edge formed opposite the base of the pentagonal cross-section. The pentagon has two perpendicular sides extending away from the base of the pentagon to two sides that converge at an edge to which the impact absorbing members 305 are secured. As another example, the modular row 110 has a triangular cross section (e.g., isosceles triangle), and the impact absorbing members 305 are secured along an edge opposite the base of the triangular cross-section. Relative to a rectangular cross-section, the tapered cross-section reduces the mass to secure the impact absorbing members 305 to the base of the modular row 110. The base of the modular row 110 is generally wider than an impact absorbing member 305 in order to form a shell when assembled with adjacent modular rows 110. The general benefit of forming the base of the rows in this manner is to increase moldability of these structures.

Branched Impact Absorbing Members

[0044] FIG. 4 is a plan view of an impact absorbing member 405 having a branched shape, in accordance with an embodiment. The impact absorbing member 405 includes a base portion 410 and two branched portions 415. The base portion 410 and the branched portions 415 are joined at one end. Opposite ends of the branched portions 415 are secured to one of the concentric surfaces 103, and the opposite end of the base portion 410 is secured to an opposite one of the concentric surfaces. Varying the angle between the branched portions 415 modifies the critical force to buckle the impact absorbing member 405. For example, increasing the angle between the branched portions 415 decreases the critical force. Generally, the angle between the branched portions 415 is between 30° and 120°. The impact absorbing structure 405 may include additional branched portions 415. For example, impact absorbing structure 405 includes three branched portions 415, one of which is parallel to the base portion 410.

Impact Absorbing Structures Including Intersecting Arches

[0045] FIG. 5A is a perspective view of impact absorbing structures 505 including intersecting arches, in accordance with an embodiment. In the illustrated example, an impact absorbing structure 505 includes two arches which each form half a circle. The portions intersect perpendicular to each other at an apex of the impact absorbing structure 505. However, other variations are possible, such as an impact absorbing structure 505 including three arches intersecting at angles of about 60°, four arches intersecting at angles of about 45°, or a single arch. In general, having two or more intersecting arches causes the impact absorbing structure 505 to have a more uniform rigidity and yield stress from torques having different lateral directions relative to a single arch. As another example, the impact absorbing structure 505 may form a dome having a uniform resistance to torques from different lateral directions, but use of distinct intersecting arches decreases the weight of the impact absorbing structure 505. Compared to a dome, the gaps between the arches in the impact absorbing structure 505 facilitate injection of foam or another less rigid material inside of the impact absorbing structure 505 to further dissipate energy.

[0046] The ends of the arches are mechanically secured to the surface 510, which may be a concentric surface 103 of a modular row or an inner or outer shell. The surface 510 may form an indentation 515 having a cross-sectional shape corresponding to (and aligned with) a projection of the impact absorbing structure 505 onto the surface 510. The indentation extends at least partway through the surface 510. For example, the indentation 515 has a cross-section of a cross to match the perpendicularly intersecting arches of the impact absorbing structure 505 secured above the indentation. When the impact absorbing structure 505 deforms as a result of a compressive force, the impact absorbing structure 505 may deflect into the indentation 515. As a result, the impact absorbing member 505 has a greater range of motion, resulting in absorption of more energy (from deformation) and slower deceleration. Without the indentation 515, a compressive force could cause the impact absorbing structure 505 to directly contact the surface 510, resulting in a sudden increase in stiffness that would limit further gradual deceleration of the impact absorbing structure 505.

[0047] FIG. 5B is a perspective view of an opposing arrangement of the impact absorbing 505 structures of FIG. 5A, in accordance with an embodiment. An upper set of impact absorbing structures 505 is secured to an outer surface 510A, and a lower set of impact absorbing structures 515 is secured to an inner surface 510B. The impact absorbing structures 505 may be aligned to horizontally overlap apexes of opposing impact absorbing structures 505, or the impact absorbing structures 505 may be aligned to horizontally offset apexes of impact absorbing structures 505 on the outer surface 510A and inner surface 510B. In the vertically aligned arrangement, the distance between the inner and outer surfaces is increased, which provides more room for deformation of the impact absorbing structures 505 to absorb energy from a collision. In the offset arrangement, the distance between the inner and outer surfaces 510 is reduced, and the area of contact between oppositely aligned impact absorbing structures 505 is increased. Although the outer surface 510A and the inner surface 510B are illustrated as being planar, they may be curved, as in a modular row or a concentric shell arrangement. In such a case, the outer surface 510A may include more impact absorbing structures 505 than the inner surface 510B, or the impact absorbing structures 505 of the outer surface 510A may be horizontally enlarged relative to those on the inner surface 510B.

[0048] FIG. 5C is a perspective view of impact absorbing structures 555 including intersecting arches 560 connected by a column 565, in accordance with an embodiment. The intersecting arches 560 may be intersecting arches, such as the impact absorbing structures 505. The column 565 may be similar to the impact absorbing members 105 and 305. As illustrated, the opposite ends of a column 565 are perpendicularly connected to two vertically aligned intersecting arches 560. Because the columns 565 are subject to different types of deformation relative to the intersecting arches (e.g., buckling and deflection), the impact absorbing structure 555 may have two or more critical forces that result in deformation of different components of the impact absorbing structure 555. In this way, the impact absorbing structure 555 may dissipate energy from a collision in multiple stages through multiple mechanisms. In other embodiments, the impact absorbing structures 505 and 555 may include any of the impact absorbing structures described with respect to FIGS. 6A through 8C.

Packed Impact Absorbing Structures

[0049] FIGS. 6A is a cross-sectional view of a helmet 600 including impact absorbing structures 615 having a spherical wireframe shape, in accordance with an embodiment. FIG. 6B is a plan view of the impact absorbing structure 615 included in the helmet 600, in accordance with an embodiment. FIG. 6C is a perspective view of the impact absorbing structure 615 included in the helmet 600, in accordance with an embodiment.

[0050] The helmet 600 includes an outer shell 605, an inner shell 610, and impact absorbing structures 615 disposed between the outer shell 605 and the inner shell 610. The impact absorbing structures 615 are formed from perpendicularly interlocked rings that together form a spherical wireframe shape. Although the illustrated impact absorbing structures 615 include three mutually orthogonal rings, other structures are possible. For example, the number of longitudinal rings may be increased to improve the uniformity of the impact absorbing structure's response to forces from different directions. However, increasing the number of rings increases the weight of the impact absorbing structure 615 and decreases the space between the rings, which hinders filling an internal volume of the impact absorbing structure 615 with a less rigid material such as foam.

[0051] The helmet 600 further includes a facemask 620, which protects a face of the wearer while allowing visibility, and vent holes 625, which improve user comfort by enabling air circulation to the user's skin. For example, the helmet 600 forms the vent holes 625 near the user's ears to improve propagation of sound waves. The vent holes 625 further serve to reduce moisture and sweat accumulating in the helmet 600. In some embodiments, the helmet includes a screen or mesh (e.g., from metal wire) placed over a vent hole 625 to reduce penetration by particles (e.g., soil, sand, snow) and to prevent penetration by blunt objects during collisions.

[0052] FIG. 7A is a cross-sectional view of a helmet 700 including impact absorbing structures 715 having a jack shape, in accordance with an embodiment. FIG. 7B is a plan view of the impact absorbing structure 715 included in the helmet 700, in accordance with an embodiment. FIG. 7C is a perspective view of the impact absorbing structure 715 included in the helmet 700, in accordance with an embodiment.

[0053] The helmet 700 includes an outer shell 605, an inner shell 610, impact absorbing structures 715 disposed between the outer shell 605 and the inner shell 610, a face mask 620, and vent holes 625. As illustrated, an impact absorbing structure 715 has a jack shape formed by three orthogonally intersecting bars, which connect a central point to faces of an imaginary cube enclosing the impact absorbing structure 715. Alternatively, the impact absorbing structures may include additional bars intersecting at a central point, such as bars that connect the central point to faces of an enclosing tetrahedron or octahedron. Compared to impact absorbing structures with a column shape, the impact absorbing structures 715 may have increased resistance to forces from multiple directions, particularly torques due to friction in a collision.

[0054] The impact absorbing structures 615 or 715 may be mechanically secured to the outer shell 605, the inner shell 610, or both. However, mechanically securing the impact absorbing structures 615 or 715 increase manufacturing complexity and may be obviated by filling the volume between the outer shell 605 and inner shell 610 with another material. This other material may secure the impact absorbing structures 615 relative to each other and the inner and outer shells, which prevents bothersome rattling.

[0055] FIGS. 8A is a cross-sectional view of a helmet 800 including impact absorbing structures 815 having a bristle shape, in accordance with an embodiment. FIG. 8B is a plan view of the impact absorbing structure 815 included in the helmet 800, in accordance with an embodiment. FIG. 8C is a perspective view of the impact absorbing structure 815 included in the helmet 800, in accordance with an embodiment.

[0056] The helmet 800 includes an outer shell 605, an inner shell 610, impact absorbing structures 815 disposed between the outer shell 605 and the inner shell 610, a face mask 620, and vent holes 625. As illustrated, an impact absorbing structure 815 has a bristle shape with multiple bristles arranged perpendicular to outer shell 605, inner shell 610, or both. The impact absorbing structure 815 further includes holes having a same diameter as the bristles. As illustrated, the holes and bristles of the impact absorbing structure are arranged in an array structure with the bristles and holes alternating across rows and columns of the array. The impact absorbing structure may include a base pad secured to the shell 605 or 610. The base pad secures the bristles and forms the holes. Alternatively, the shells 605 and 610 serve as base structures that secure the bristles and forms the holes. Impact absorbing structures 815 on the shells 605 and 610 are aligned oppositely and may be offset so that bristles of an upper impact absorbing structure 815 are aligned with holes of the lower impact absorbing structure 815, and vice versa. In this way, the ends of bristles may be laterally secured when the opposing impact absorbing structures 815 are assembled between the outer shell 605 and the inner shell 610.

[0057] In some embodiments, the impact absorbing structures 615, 715, or 815 are secured in a ridge that protrudes from an outer shell of the helmet 100 (e.g., like a mohawk). In this way, the ridge may absorb energy from a collision before the force is transmitted to the outer shell of the helmet 100.

Additional Impact Absorbing Structures

[0058] FIG. 9 is a perspective view of an embodiment of an impact absorbing structure 910 having a conical structure. In the example shown by FIG. 9, the impact absorbing structure 910 has a circular base 915 coupled to a circular top 920 via a conical structure 925. As shown in FIG. 9, a portion of the conical structure 925 coupled to the circular base 915 has a smaller diameter than an additional portion of the conical structure 925 coupled to the circular top 920 of the impact absorbing structure 910. In various embodiments, the interior of the conical structure 925 is hollow. Alternatively, a less rigid material, such as foam, may be injected into the interior of the conical structure 925 to further dissipate energy from an impact. In various embodiments, the circular base 915 is configured to be coupled to an inner shell of a helmet, while the circular top 920 is configured to be coupled to an outer shell of a helmet, such as the helmet described above in conjunction with FIGS. 6A, 7A, and 8A Alternatively, the circular base 915 is configured to be coupled to an outer shell of a helmet, while the circular top 920 is configured to be coupled to an inner shell of a helmet, such as the helmet described above in conjunction with FIGS. 6A, 7A, and 8A

[0059] FIG. 10 is a perspective view of an embodiment of an impact absorbing structure 1005 having a base portion 1010 and angled support portions 1015A, 1015B (also referred to individually and collectively using reference number 1015). The impact absorbing structure 405 includes a base portion 410 and two branched portions 415. The base portion 1010 is coupled to each of the concentric surfaces 103 further described above in conjunction with FIG. 2, while a support portion 1015A has an end coupled to the base portion 1010 and another end coupled to one or the concentric surfaces 103. In the example shown by FIG. 10, each base portion 1010 has two support portions 1015A coupled to the base portion 1010 and to one of the concentric surfaces 103 and also has two additional support portions 1015B coupled to the base portion 1010 and to the other concentric surface 103. However, in other embodiments, the base portion 1010 has any suitable number of support portions 1015 coupled to the base portion 1010 and to one of the concentric surfaces 103. In some embodiments, the base portion includes different numbers of support portions 1015 coupled to the base portion and to a concentric surface 103 and coupled to the other concentric surface 103.

[0060] A support portion 1015 is coupled to the base portion 1010 at an angle and is coupled to a concentric surface 103 at an additional angle. In various embodiments, the angle equals the additional angle. Varying the angle at which the support portion 1015 is coupled to the base portion 1010 or the additional angle at which the support portion 1015 is coupled to the concentric surface 103 modifies a critical force that, when applied, cause the impact absorbing member 1005 to buckle.

[0061] FIG. 11 is a perspective view of an embodiment of an impact absorbing structure 1105 having a cylindrical member coupled to multiple planar surfaces 1115A, 1115B (also referred to individually and collectively using reference number 1115). In the example shown by FIG. 9, the cylindrical member has a vertical portion 1112 having a height and having a circular base 1110 at one end. At an opposite end of the vertical portion 1112 from the circular base 110, multiple planar surfaces 1115A, 1115B are coupled to the vertical portion 1112. Different planar surfaces 1115 are separated by a distance 1120. For example, FIG. 11 shows planar surface 1115A separated from planar surface 1115B by the distance 1120. In various embodiments, each planar surface 1115 is separated from an adjacent planar surface 1115 by a common distance 1120; alternatively, different planar surfaces 1115 are separated from other planar surfaces 1115 by different distances 1120. Each planar surface 1115 has a width 1125, while FIG. 11 shows an embodiment where the width 1125 of each planar surface 1115 is the same, different planar surfaces 1115 may have different widths in 1125 in other embodiments. The planar surfaces 1115 are coupled to the opposite end of the vertical portion 1112 of the cylindrical member than the circular base 1110 around a circumference of the cylindrical member. Additionally, the circular base 1110 is configured to be coupled to an outer shell of a helmet, while ends of the planar surfaces 1115A, 1115B not coupled to the vertical portion of the cylindrical member are configured to be coupled to an inner shell of a helmet, such as the helmet described above in conjunction with FIGS. 6A, 7A, and 8A. Alternatively, the circular base 1110 is configured to be coupled to an inner shell of a helmet, while ends of the planar surfaces 1115A, 1115B not coupled to the vertical portion of the cylindrical member are configured to be coupled to an outer shell of a helmet, such as the helmet described above in conjunction with FIGS. 6A, 7A, and 8A In other embodiments, the circular base 1110 is configured to be coupled to a concentric surface 103 and the ends of the planar surfaces 1115A, 1115B not coupled to the vertical portion of the cylindrical member are configured to be coupled to another concentric surface 103.

[0062] FIG. 12 is a perspective view of an embodiment of an impact absorbing structure 1205 having a base portion 1210 to which multiple supplemental portions 1215A, 1215B (also referred to individually and collectively using reference number 1215) are coupled. Support portions 1220A, 1220B (also referred to individually and collectively using reference number 1220) are coupled to a concentric surface 103 and to a supplemental portion 1215A, 1215B. As shown in FIG. 12, an end of a supplemental portion 1215A is coupled to the base portion 1210, while an opposing end of the supplemental portion 1215A is coupled to a support portion 1220A. The support portion 1220A has an end coupled to the opposing end of the supplemental portion 1215A, while another end of the support portion 1220A is coupled to a concentric surface 103. In various embodiments, an end of the base portion 1210 and the other ends of the support portions 1220 are each coupled to a common concentric surface 103, while an opposing end of the base portion 1210 is coupled to a different concentric surface 103.

[0063] Any number of supplemental portions 1215 may be coupled to the base portion 1210 of the impact absorbing structure in various embodiments. Additionally, the supplemental portions 1215 are coupled to the base portion 1210 at an angle relative to an axis parallel to the base portion 1210. In some embodiments, each supplemental portion 1215 is coupled to the base portion 1210 at a common angle relative to the axis parallel to the base portion 1210. Alternatively, different supplemental portions 1215 are coupled to the base portion 1210 at different angles relative to the axis parallel to the base portion 1210. Similarly, each support portion 1220 is coupled to a supplemental portion 1215 at an angle relative to an axis parallel to the supplemental portion 1215. In some embodiments, each support portion 1220 is coupled to a corresponding supplemental portion 1215 at a common angle relative to the axis parallel to the supplemental portion 1215. Alternatively, different support portions 1220 are coupled to a corresponding supplemental portion 1215 at different angles relative to the axis parallel to the corresponding supplemental portion 1215.

[0064] FIG. 13A is a perspective view of an embodiment of a conical impact absorbing structure 1305. The conical impact absorbing structure 1305 has a circular base 1315 and an additional circular base 1320 that has a smaller diameter than the circular base 1315. A vertical member 1310 is coupled to the circumference of the circular base 1315 and to a circumference of the additional circular base 1320. Hence, a width of the vertical member 1310 is larger nearer to the circular base 1315 and is smaller nearer to the additional circular base 1320. The circular base 1315 is configured to be coupled to a concentric surface 103, while the additional circular base 1320 is configured to be coupled to an additional concentric surface 103. In the example shown by FIG. 13A, the vertical member 1310 is hollow. Alternatively, a less rigid material, such as foam, may be injected into the interior of the vertical member 1310 to further dissipate energy from an impact.

[0065] FIG. 13B is a cross-sectional view of an alternative impact absorbing structure 1330. In the example shown by FIG. 13B, the alternative impact absorbing structure 1330 has a circular base 1340 and an additional circular base 1345 that each have a common diameter. A vertical member 1350 is coupled to the circular base 1340 and to the additional circular base 1345. Because the diameter of the circular base 1340 equals the diameter of the additional circular base 1345, the vertical member 1350 has a uniform width between the circular base 1340 and the additional circular base 1345. In the example of FIG. 13B, the vertical member 1350 is hollow. Alternatively, a less rigid material, such as foam, may be injected into the interior of the vertical member 1350 to further dissipate energy from an impact. The circular base 1345 is configured to be coupled to a concentric surface 103, while the additional circular base 1350 is configured to be coupled to an additional concentric surface 103.

[0066] FIG. 14 is a side view of an impact absorbing structure 1405 having arched structures 1410A, 1410B. In the example shown by FIG. 4, the impact absorbing structure 1405 has an arched structure 1410A coupled to a concentric surface 103 at an end and coupled to another concentric surface 103 at an opposing end. Similarly, an additional arched structure 1410B is coupled to the concentric surface 103 at an end, while an opposing end of the additional arched structure 1410B is coupled to the other concentric surface 103. A bracing member 1415 is positioned in a plane parallel to the concentric surface 103 and the other concentric surface 103. An end of the bracing member 1415 is coupled to the arched structure 1410A, while an opposing end of the bracing member 1415 is coupled to the additional arched structure 1410B. In various embodiments, the end of the bracing member 1415 is coupled to the arched structure 1410A at an apex of the arched structure 1410B relative to an axis perpendicular to the bracing member 1415. Similarly, the opposing end of the bracing member 1415 is coupled to the additional arched structure 1410B at an apex of the additional arched structure 1410B relative to the axis perpendicular to the bracing member 1415. However, in other embodiments, the bracing member 1415 may be coupled to any suitable portions of the arched structure 1410A and the additional arched structure 1410B along a plane parallel to the concentric surface 103 and the other concentric surface 103.

[0067] Additionally, a supporting structure 1420A is coupled to a portion of a surface of the bracing member 1415 and to an additional portion of the surface of the bracing member 1415. Similarly, an additional supporting structure 1420B is coupled to a portion of an additional surface of the bracing member 1415 that is parallel to the surface of the bracing member 1415 and to an additional portion of the additional surface of the bracing member 1415. As shown in FIG. 14, the supporting structure 1420A is arched between the portion of the surface of the bracing member 1415 and the additional portion of the surface of the bracing member 1415. Similarly, the additional supporting structure 1420B is arched between the portion of the additional surface of the bracing member 1415 and the additional portion of the additional surface of the bracing member 1415.

[0068] FIG. 15 is a perspective and cross-sectional view of an embodiment of an impact absorbing structure 1505 comprising a cylindrical structure 1510 enclosing a conical structure 1515. In the example shown by FIG. 15, the impact absorbing structure 1505 has a cylindrical structure 1510 having an interior wall 1535 and an exterior wall. The cylindrical structure 1510 encloses a conical structure 1515 having a circular base1520 at one end and an additional circular base 1525 at an opposing end. In various embodiments, the cylindrical structure 1510 and the conical structure 1515 each have different durometers, so the cylindrical structure 1510 and the conical structure 1515 have different hardnesses. Alternatively, the cylindrical structure 1510 and the conical structure 1515 have a common hardness. The additional circular base 1525 has a smaller diameter than the circular base 1520. Additionally, the interior wall 1535 of the cylindrical structure 1510 tapers from a portion of the cylindrical structure 1510 nearest the additional circular base 1525 of the conical structure 1515 to being coupled to a circumference of the circular base 1520 of the conical structure 1515. In some embodiments, such as shown in FIG. 15, a height of the conical structure 1515 is greater than a height of the cylindrical structure 1510, so the additional circular base 1525 of the conical structure 1515 protrudes above the cylindrical structure 1510. Alternatively, the height of the conical structure 1515 equals the height of the cylindrical structure 1510, so a top of the cylindrical structure 1510 is in a common plane as the additional circular base 1525 of the conical structure 1515. Alternatively, the height of the conical structure 1515 is less than the height of the cylindrical structure 1510. As an additional example, the conical structure 1515 and the cylindrical structure 1510 have equal heights. In various embodiments, the circular base 1520 of the conical structure 1515 is configured to be coupled to an inner shell of a helmet, while the additional circular base 1525 of the conical structure 1515 is configured to be coupled to an outer shell of a helmet, such as the helmet described above in conjunction with FIGS. 6A, 7A, and 8A. Alternatively, the circular base 1520 of the conical structure 1515 is configured to be coupled to an outer shell of a helmet, while the additional circular base 1525 of the conical structure 1515 is configured to be coupled to an inner shell of a helmet, such as the helmet described above in conjunction with FIGS. 6A, 7A, and 8A

[0069] FIG. 16 shows an embodiment of an impact absorbing structure 1605. In the example shown by FIG. 16, the impact absorbing structure 1605 is a surface that undulates in a plane perpendicular to a plane including a concentric surface 103 and is coupled at one end to the concentric surface 103 and is coupled at an opposing end to an additional concentric surface 103. For example, the impact absorbing structure 1605 has a sinusoidal cross section in a plane parallel to the plane including the concentric surface 103. However, in other embodiments, the impact absorbing structure 1605 has any suitable profile in a cross section along the plane parallel to the plane including the concentric surface 103.

[0070] FIGS. 17A-17C show perspective views of impact absorbing structures 1700A, 1700B, 1700C comprising connected support members 1705, 1710. Each support member 1705, 1710 has an end configured to be coupled to a concentric surface 103 and an opposing end configured to be coupled to another concentric surface 103. A support member 1705 is coupled to the other support member 1710 by a connecting element that is in a plane perpendicular to a plane including the concentric surface 103, or in a plane perpendicular to another plane including the other concentric surface 103. In the example of FIG. 17A, an impact absorbing structure 1700A includes a rectangular structure 1715A connecting the support member 1705 to the other support member 1710 and perpendicular to the concentric surface 103 and to the other concentric surface 103. In various embodiments, an end of the rectangular structure 1715A is coupled to the concentric surface 103, while an opposite end of the rectangular structure 1715A is coupled to the other concentric surface 103.

[0071] FIG. 17B shows an impact absorbing structure 1700B including an arched structure 1715B connecting the support member 1705 to the other support member 1710.

The arched structure 1715B is perpendicular to the concentric surface 103 and to the other concentric surface 103 and is arched in a plane that is parallel to the concentric surface 103 and to the other concentric surface 103. In various embodiments, an end of the arched structure 1715B is coupled to the concentric surface 103, while an opposite end of the arched structure 1715B is coupled to the other concentric surface 103.

[0072] FIG. 17C shows an impact absorbing structure 1700B including an undulating structure 1715C connecting the support member 1705 to the other support member 1710. The undulating structure 1715C is perpendicular to the concentric surface 103 and to the other concentric surface 103 and includes multiple arcs in a plane that is parallel to the concentric surface 103 and to the other concentric surface 103. For example, the undulating structure 1715C has a sinusoidal cross section in a plane parallel to the plane including a concentric surface 103. In various embodiments, an end of the undulating structure 1715C is coupled to the concentric surface 103, while an opposite end of the undulating structure 1715C is coupled to the other concentric surface 103.

[0073] While FIGS. 17A-17C show examples of impact absorbing structures where a pair of support members are coupled to each other by a connecting member, any number of support members may be positioned relative to each other and different pairs of the support members connected to each other by connecting members to form structural groups. FIGS. 18-20 show example structural groups including multiple support members positioned relative to each other with different support members coupled to each other by connecting members. FIG. 18 shows an impact absorbing structure 1800 having a central support member 1805 coupled to three radial support members 1810A, 1810B, 1810C that are positioned along a circumference of a circle having an origin at the central support member 1805. The central support member 1800 is coupled to radial support member 1810A by connecting member 1815A and is coupled to radial support member 1810B by connecting member 1815B. Similarly, the central support member 1800 is coupled to radial support member 1810C by connecting member 1815C. While FIG. 18 shows an example where the connecting member 1815A, 1815B, 1815C are rectangular, while in other embodiments, the connecting members 1815A, 1815B, 1815C may be arched structures or undulating structures as described in FIGS. 17B and 17C or may have any other suitable cross section.

[0074] FIGS. 19A and 19B show perspective views of an impact absorbing structure 1900A, 1900B comprising six support members coupled to each other by connecting members to form a hexagon. In the example shown by FIG. 19A, the impact absorbing structure 1900A has pairs of support members coupled to each other via rectangular connecting members to form a hexagon. The impact absorbing structure 1900B shown by FIG. 19B has pairs of support members coupled to each other via undulating support members to form a hexagon.

[0075] FIG. 20 is a perspective view of an impact absorbing structure 2000 comprising rows of offset support members coupled together via connecting members. In the example of FIG. 20, support members are positioned in multiple parallel rows 2010, 2020, 2030, 2040, with support members in a row offset from each other so support members in adjacent rows are not in a common plane parallel to the adjacent rows. For example, support members in row 2010 are positioned so they are not in a common plane parallel to support members in row 2020. As shown in the example of FIG. 20, a support member in row 2020 is positioned so it is between support members in row 2010. Connecting members connect support members in a row 2010 to support members in an adjacent row 2020. In some embodiments, support members in a row 2010 are not connected to other support members in the row 2010, but are connected to a support member in an adjacent row 2020 via a support member 2015.

[0076] Although described throughout with respect to a helmet, the impact absorbing structures described herein may be applied with other garments such as padding, braces, and protectors for various joints and bones.

Additional Configuration Considerations

[0077] The foregoing description of the embodiments of the disclosure has been presented for the purpose of illustration; it is not intended to be exhaustive or to limit the disclosure to the precise forms disclosed. Persons skilled in the relevant art can appreciate that many modifications and variations are possible in light of the above disclosure.

[0078] The language used in the specification has been principally selected for readability and instructional purposes, and it may not have been selected to delineate or circumscribe the inventive subject matter. It is therefore intended that the scope of the disclosure be limited not by this detailed description, but rather by any claims that issue on an application based hereon. Accordingly, the disclosed embodiments are intended to be illustrative, but not limiting, of the scope of the disclosure.

What is claimed is

1. A helmet comprising:

an inner shell formed to partially enclose a portion of a wearer's head;

an outer shell enclosing the portion of the wearer's head concentrically with the inner shell; and

a plurality of impact absorbing structures partially filling a volume between the inner shell and the outer shell, an impact absorbing structure having a proximal end contacting the inner shell and a distal end contacting the outer shell.

2. The helmet of claim 1, wherein the impact absorbing structure comprises:

a base portion having an end coupled to the inner shell; and

a plurality of branched portions, each branched portion having an end coupled to the outer shell of the helmet to form an angle between the branched portions, and each branched portion having an additional end coupled to an additional end of the base portion opposite the end of the base portion coupled to the inner shell.

3. The helmet of claim 2, wherein the angle between the branched portions is between 30 degrees and 120 degrees.

4. The helmet of claim 1, wherein the impact absorbing structure comprises two arches that intersect perpendicular to each other at an apex of the impact absorbing structure, each arch forming half a circle and secured to the inner shell of the helmet.

5. The helmet of claim 4, wherein the inner shell of the helmet has an indentation aligned with a projection of the impact absorbing structure on the surface, the indentation having a cross-sectional shape corresponding to the impact absorbing structure.

6. The helmet of claim 1, wherein the impact absorbing structure comprises three arches that intersect perpendicular to each other at an apex of the impact absorbing structure at angles of 60 degrees, each arch forming half a circle.

7. The helmet of claim 1, wherein the impact absorbing structure comprises a plurality of perpendicularly interlocked rings that together form a spherical wireframe shape.

8. The helmet of claim 1, wherein the impact absorbing structure comprises a jack shape formed by three orthogonally intersecting bars that connect a central point to faces of an imaginary cube enclosing the impact absorbing structure.

9. The helmet of claim 1, wherein the impact absorbing structure comprises a circular base coupled to a circular top via a conical structure, the circular base coupled to the inner shell of the helmet.

10. The helmet of claim 9, wherein the conical structure has a hollow interior.

11. The helmet of claim 1, wherein the impact absorbing structure comprises:
a base portion coupled to the inner shell of the helmet and coupled to the outer shell of the helmet;
a plurality of support portions, each support portion coupled to the base portion at an angle and coupled to and to the outer shell of the helmet at an additional angle.

12. The helmet of claim 1, wherein the impact absorbing member comprises:
a base portion coupled to the inner shell of the helmet and coupled to the outer shell of the helmet;
a plurality of supplemental portions, each supplemental portion having an end coupled to the base portion; and
a plurality of support portions, each support portion coupled to an opposing end of a corresponding supplemental portion and coupled to the outer surface of the helmet.

13. The helmet of claim 1, wherein the impact absorbing member comprises a circular base coupled to the inner shell of the helmet, an additional circular base coupled to the outer shell of the helmet and having a smaller diameter than a diameter of the circular base, and a vertical member coupling to a circumference of the circular base to a circumference of the additional circular base.

14. An apparatus comprising:
an inner shell;
an outer shell concentric with the inner shell; and
a plurality of impact absorbing structures partially filling a volume between the inner shell and the outer shell, an impact absorbing structure having a

proximal end contacting the inner shell and a distal end contacting the outer shell.

15. The apparatus of claim 14, wherein the impact absorbing structure comprises:

a base portion having an end coupled to the inner shell; and

a plurality of branched portions, each branched portion having an end coupled to the outer shell of the helmet to form an angle between the branched portions, and each branched portion having an additional end coupled to an additional end of the base portion opposite the end of the base portion coupled to the inner shell.

16. The apparatus of claim 15, wherein the angle between the branched portions is between 30 degrees and 120 degrees.

17. The apparatus of of claim 14, wherein the impact absorbing structure comprises two arches that intersect perpendicular to each other at an apex of the impact absorbing structure, each arch forming half a circle and secured to the inner shell of the apparatus.

18. The apparatus of claim 17, wherein the inner shell of the apparatus has an indentation aligned with a projection of the impact absorbing structure on the surface, the indentation having a cross-sectional shape corresponding to the impact absorbing structure.

19. The apparatus of claim 14, wherein the impact absorbing structure comprises three arches that intersect perpendicular to each other at an apex of the impact absorbing structure at angles of 60 degrees, each arch forming half a circle.

20. The apparatus of claim 14, wherein the impact absorbing member comprises:

a base portion coupled to the inner shell of the helmet and coupled to the outer shell of the apparatus;

a plurality of supplemental portions, each supplemental portion having an end coupled to the base portion; and

a plurality of support portions, each support portion coupled to an opposing end of a corresponding supplemental portion and coupled to the outer surface of the apparatus.

21. An apparatus comprising:

an inner shell;

an outer shell concentric with the inner shell; and

a plurality of impact absorbing structures partially filling a volume between the inner shell and the outer shell, an impact absorbing structure comprising a support member having a proximal end contacting the inner shell and a distal end contacting the outer shell, an additional support member having an additional proximal end contacting the inner shell and an additional distal end contacting the outer shell, and a connecting member coupling the support member to the additional support member.

22. The apparatus of claim 21, wherein the connecting member comprises a rectangular structure perpendicular to the inner shell and perpendicular to the outer shell.

23. The apparatus of claim 21, wherein a proximal end of the rectangular structure contacting the inner shell and a distal end of the rectangular structure contacts the outer shell.

24. The apparatus of claim 21, wherein the connecting member comprises an arched structure perpendicular to the inner shell and perpendicular to the outer shell and arched in a plane parallel to the inner shell and to the outer shell.

25. The apparatus of claim 24, wherein a proximal end of the arched structure contacting the inner shell and a distal end of the arched structure contacts the outer shell.

26. The apparatus of claim 20 wherein an impact absorbing structure comprises a structural group comprising a plurality of support members positioned relative to each other and having pairs of support members coupled to each other by connecting members.

27. The apparatus of claim 26, ,wherein the structural group comprises a central support member and a plurality of radial support members positioned along a circumference of a circle having an origin of the support member and a plurality of connecting members, each connecting member coupling the central support member to a radial support member.

28. The apparatus of claim 26,wherein the structural group comprises six support members coupled to each other by a plurality of connecting members to form a hexagon.

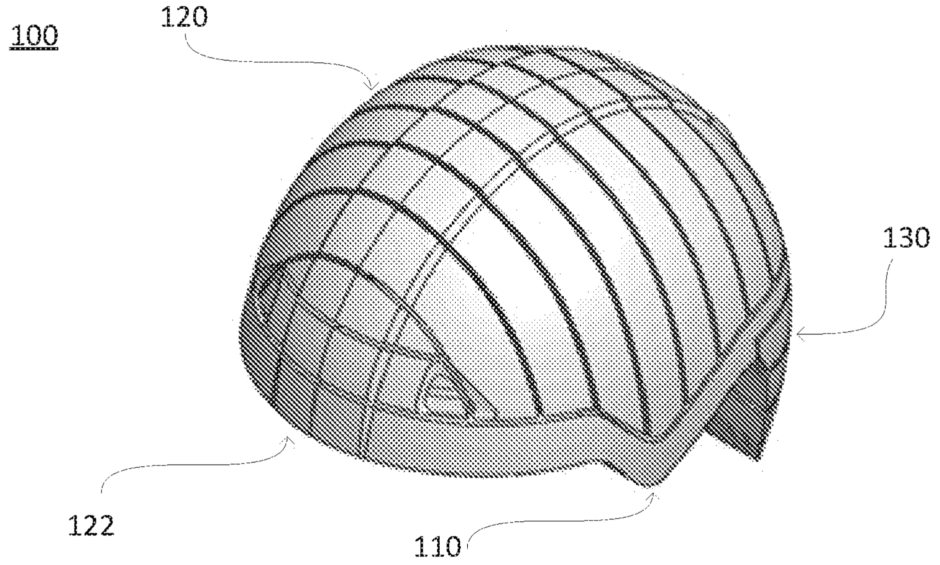

FIG. 1

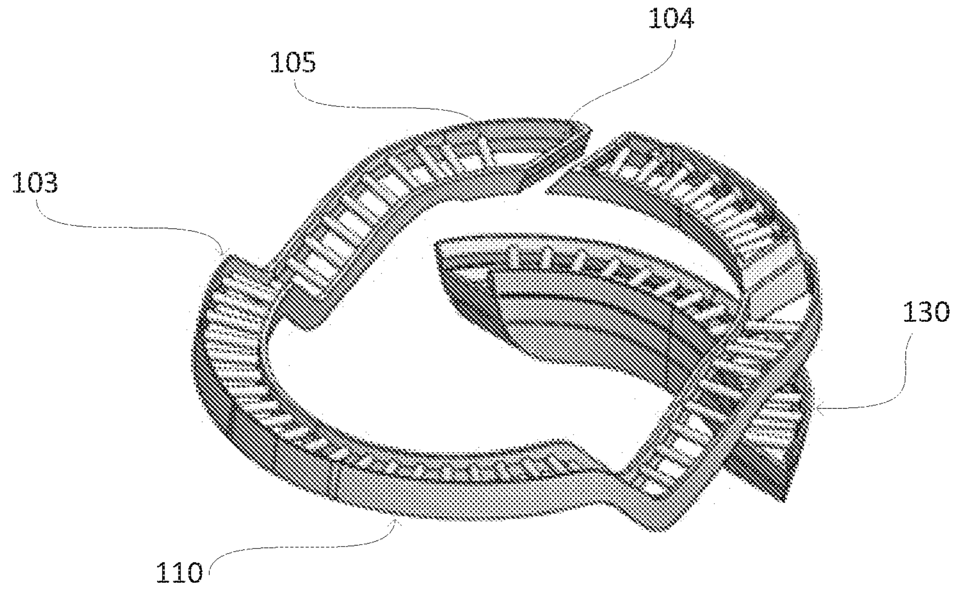

FIG. 2

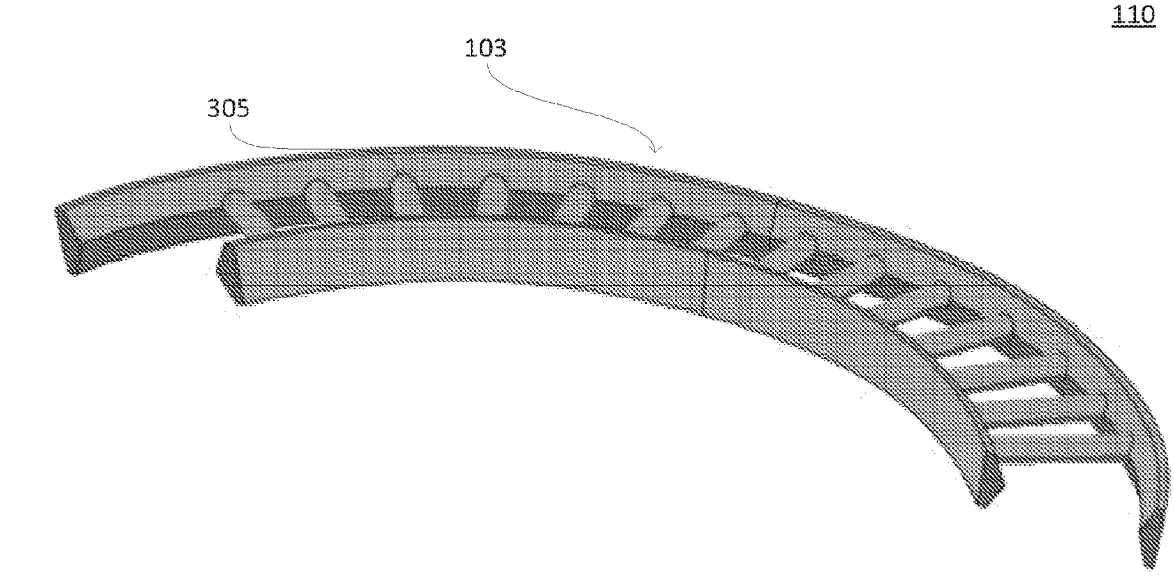

FIG. 3

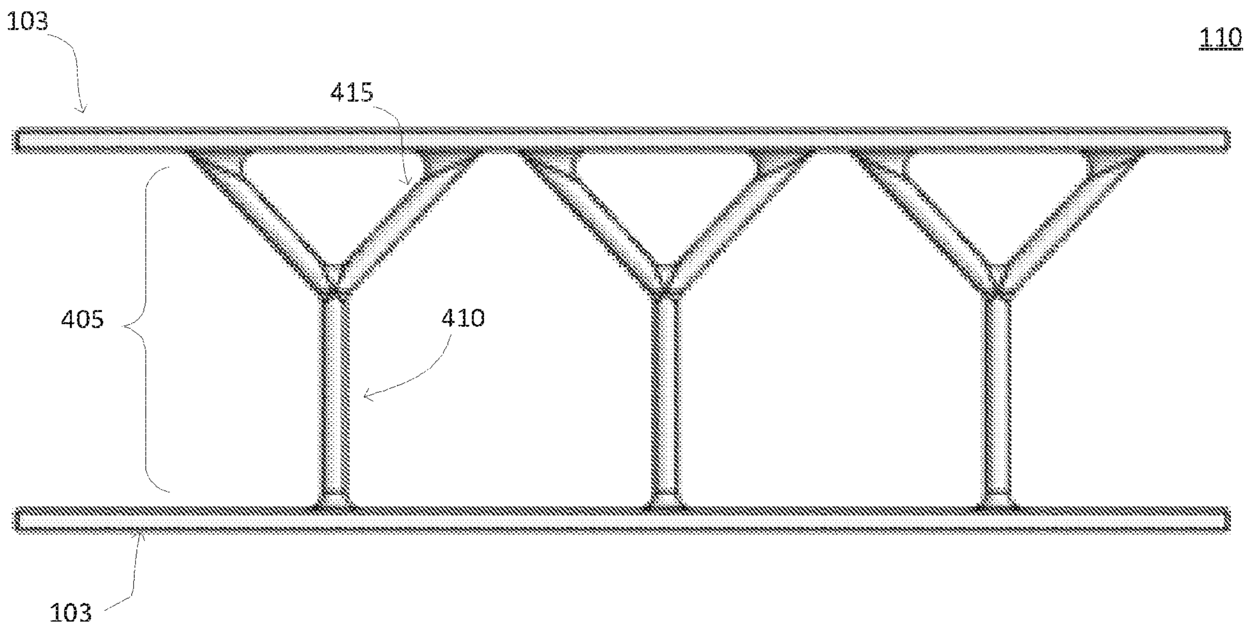

FIG. 4

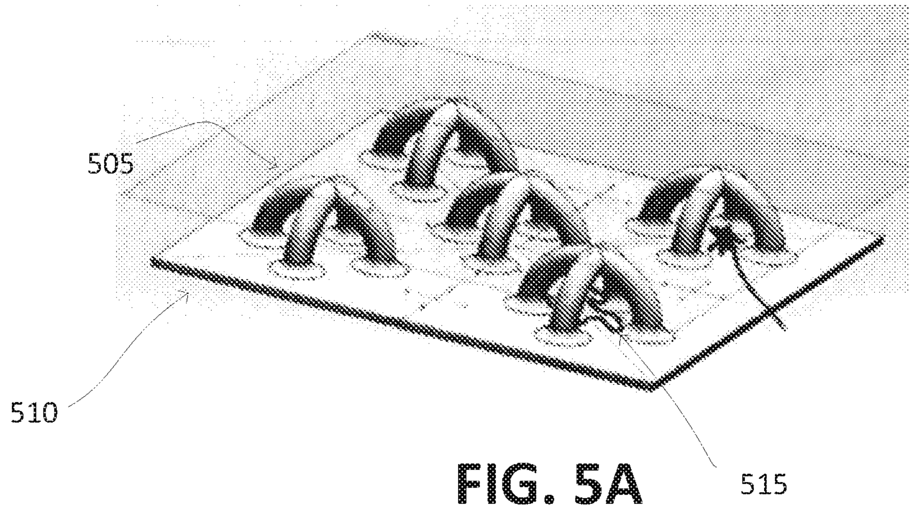

FIG. 5A

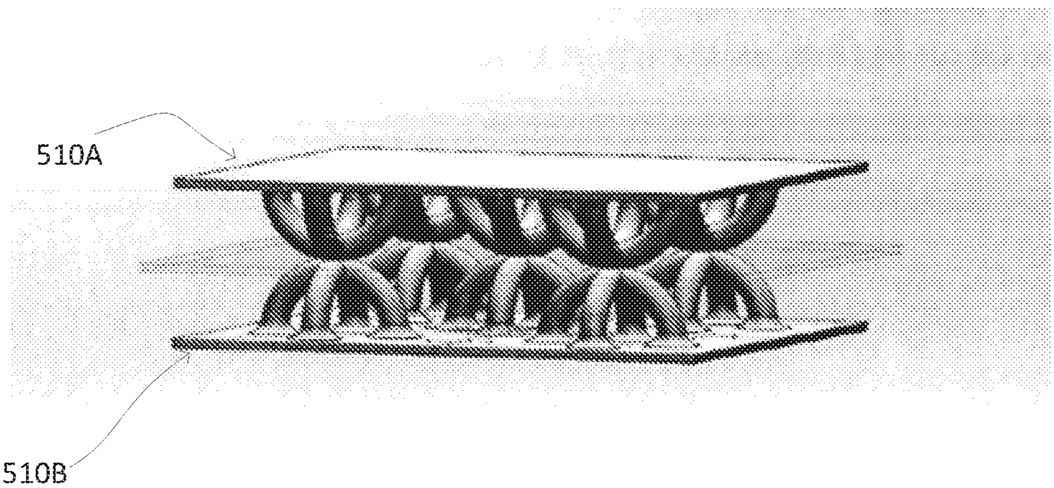

FIG. 5B

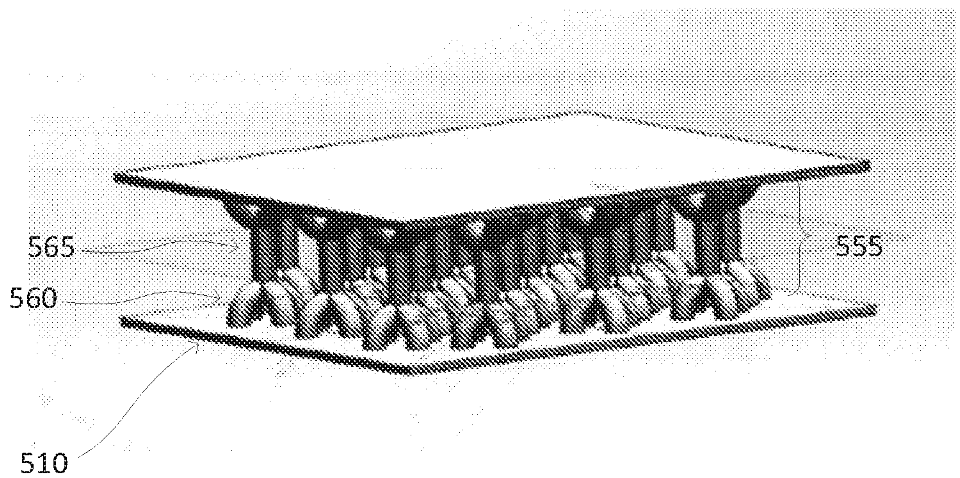

FIG. 5C

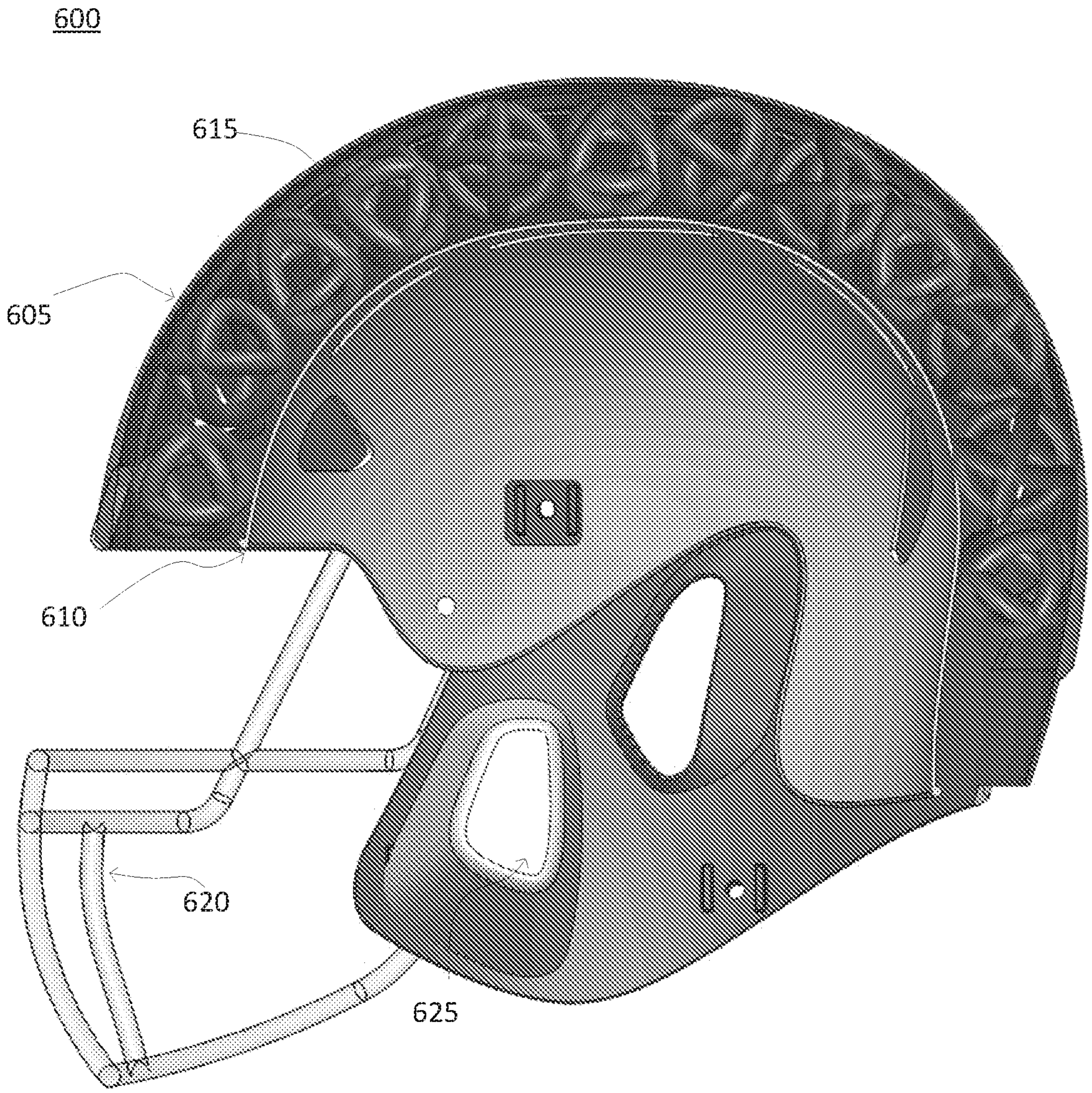

FIG. 6A

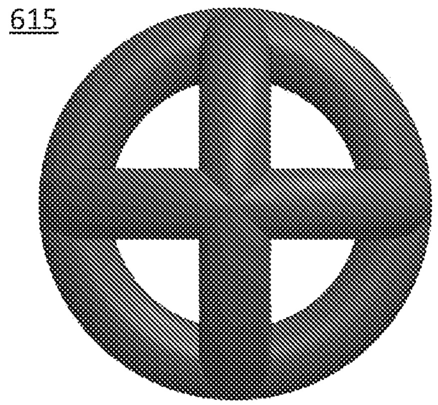

FIG. 6B

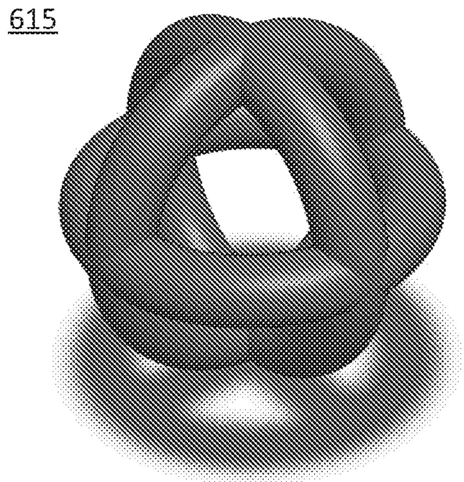

FIG. 6C

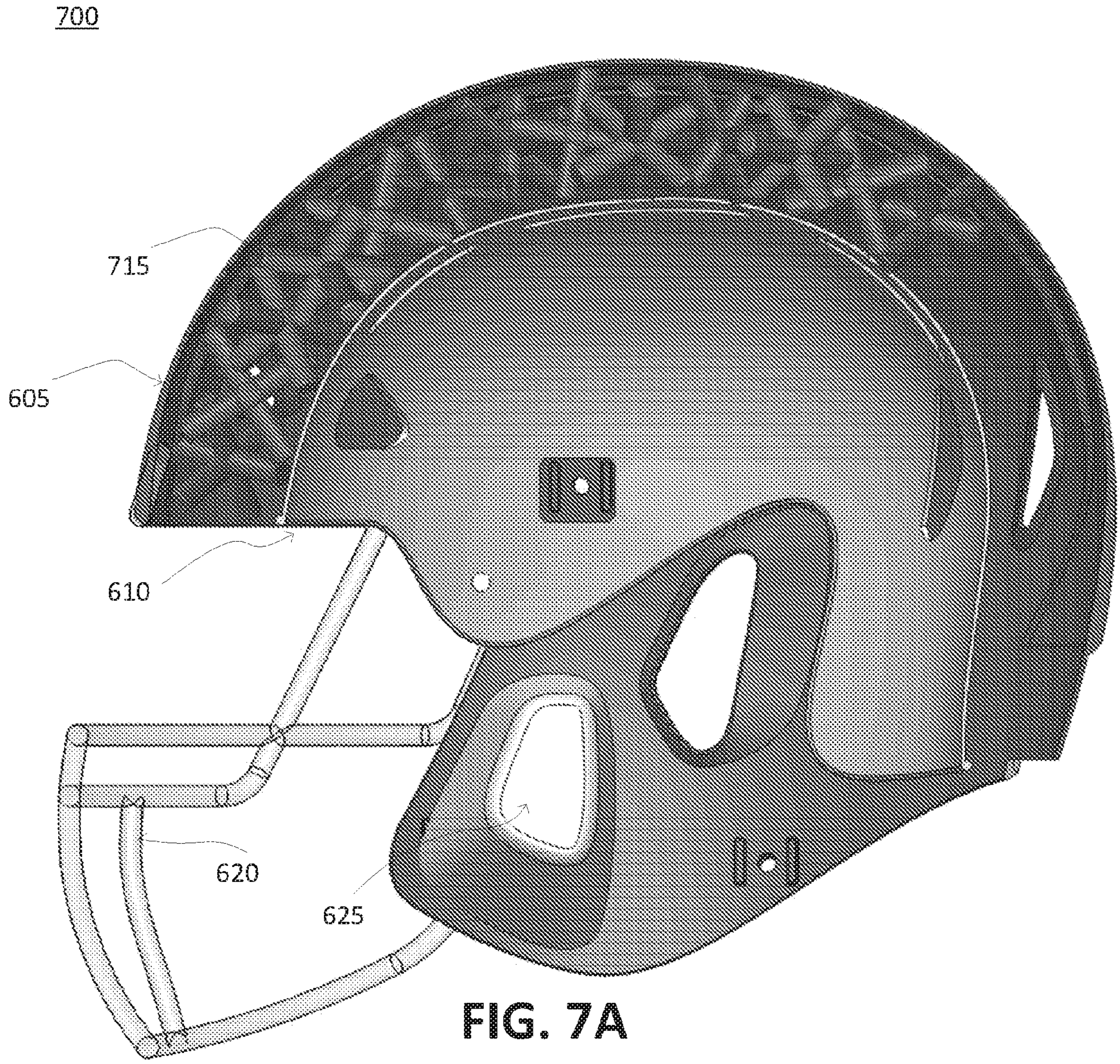

FIG. 7A

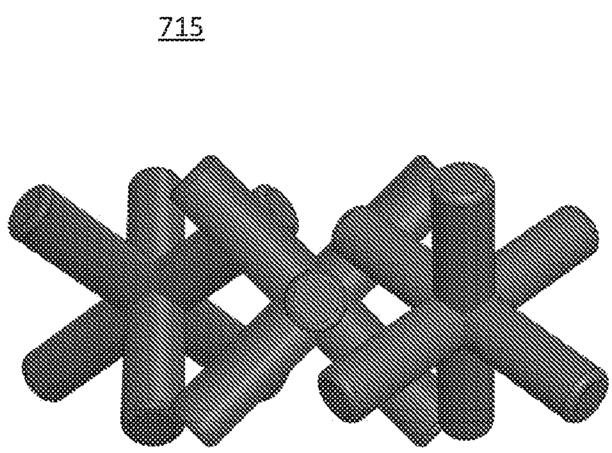

FIG. 7B

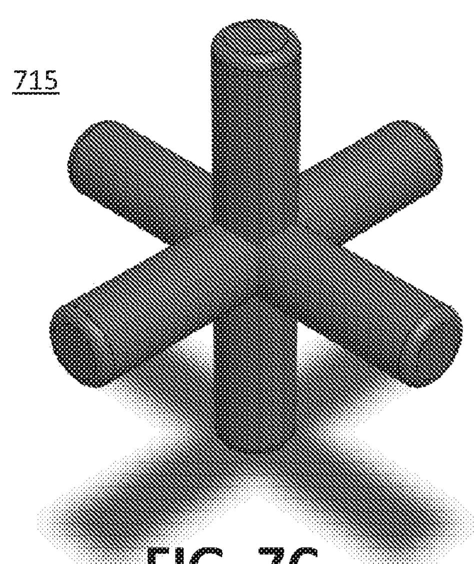

FIG. 7C

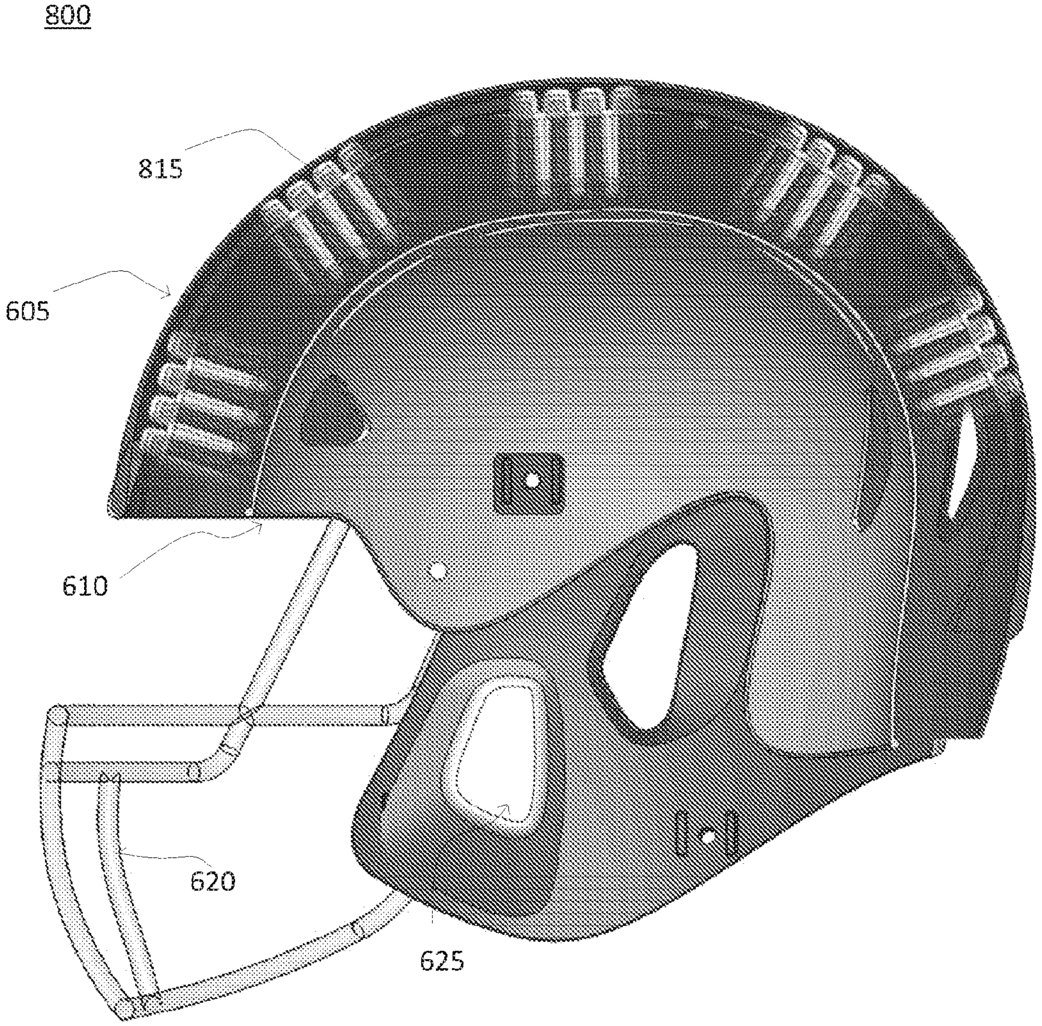

FIG. 8A

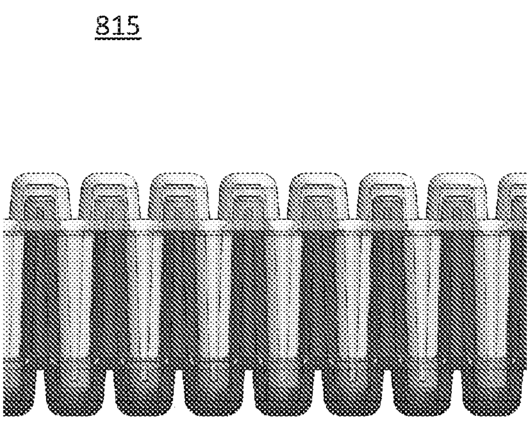

FIG. 8B

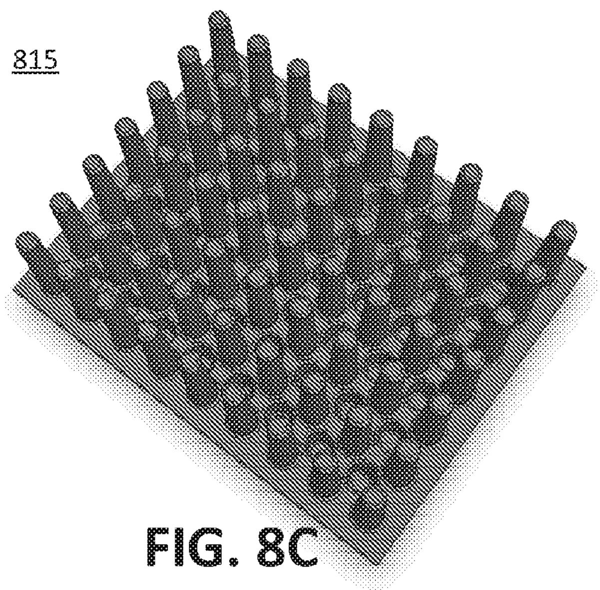

FIG. 8C

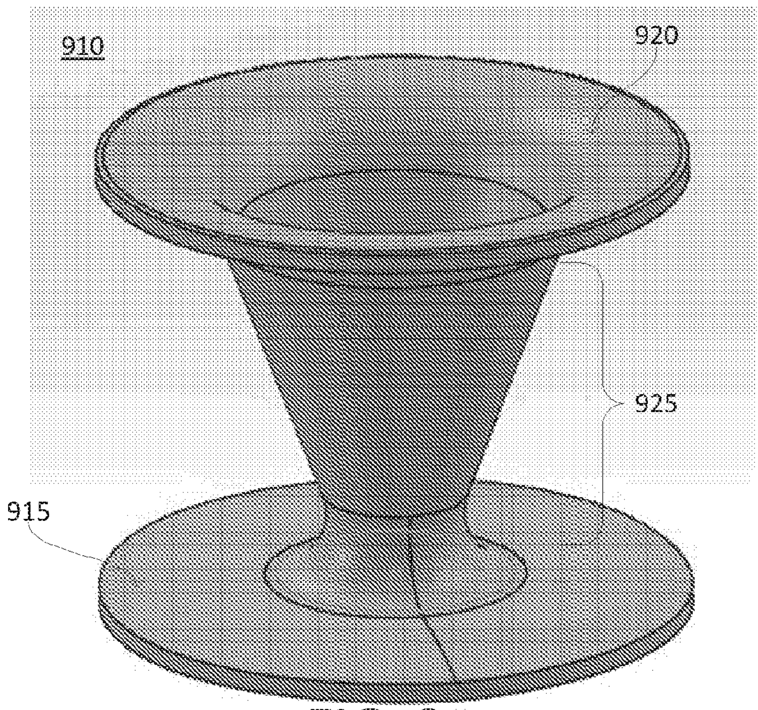

FIG. 9

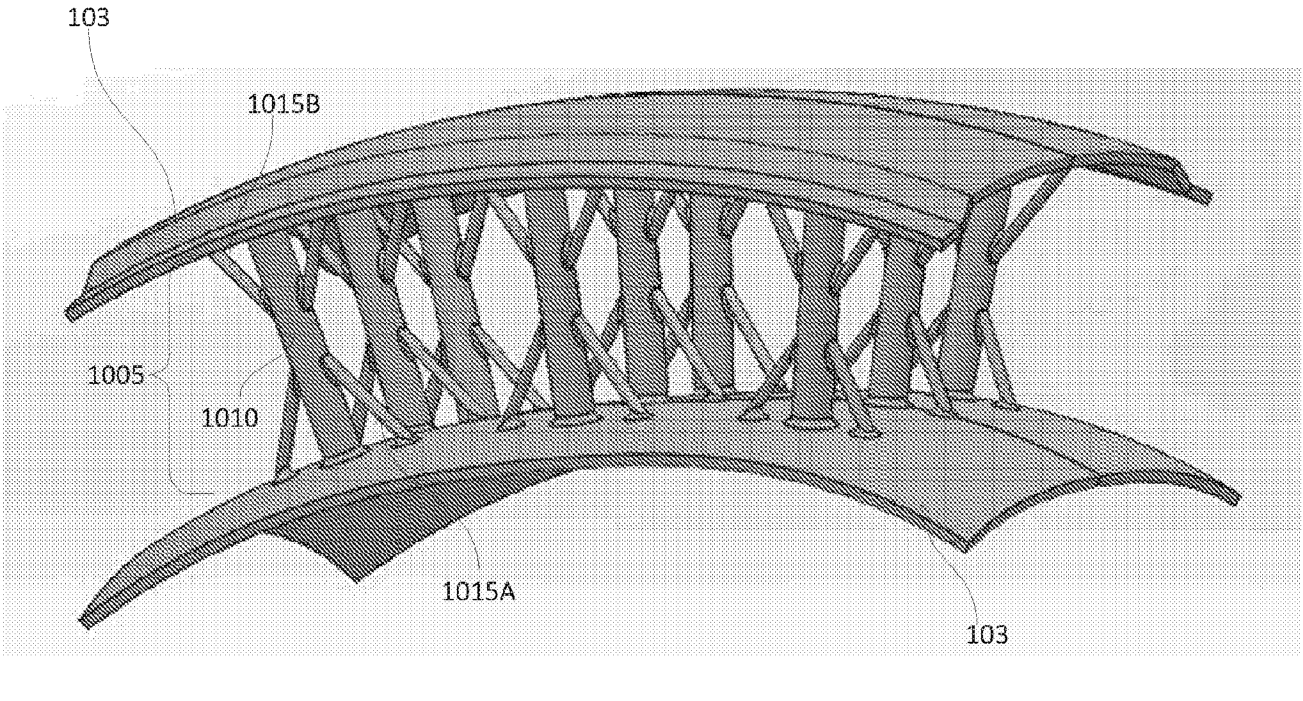

FIG. 10

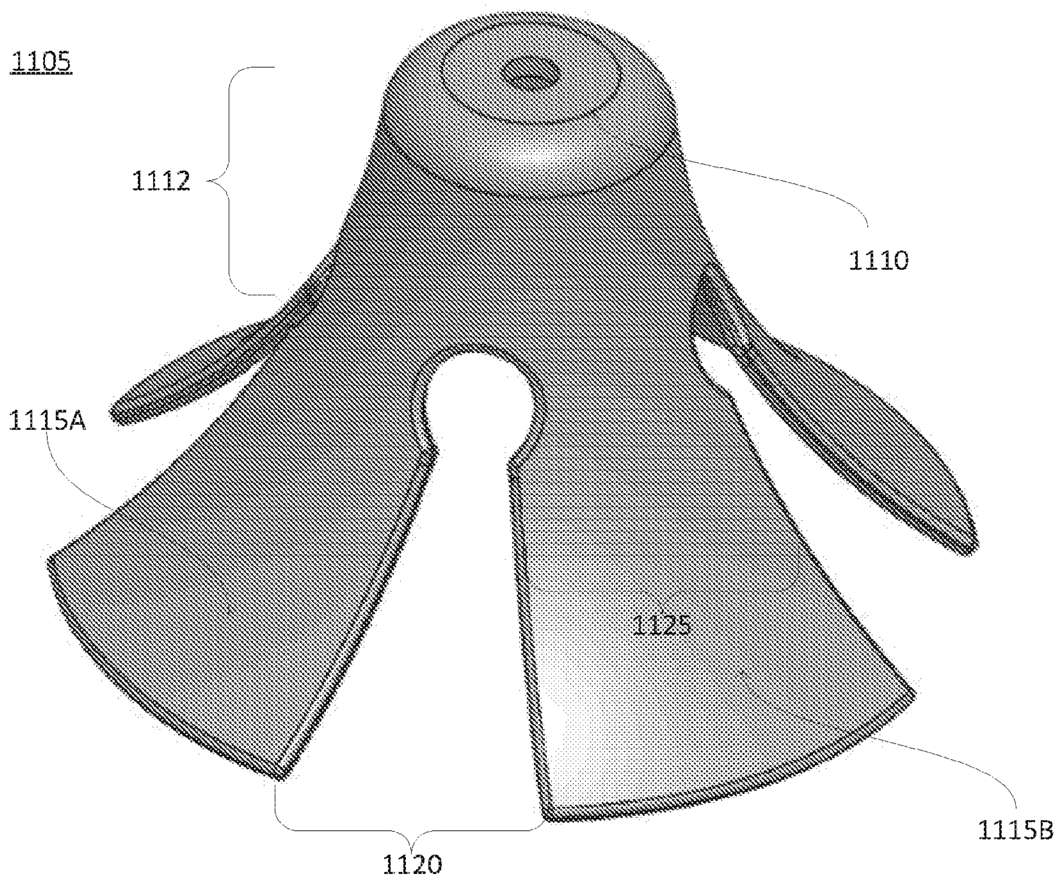
1105
1112
1110
1115A
1125
1115B
1120

FIG. 11

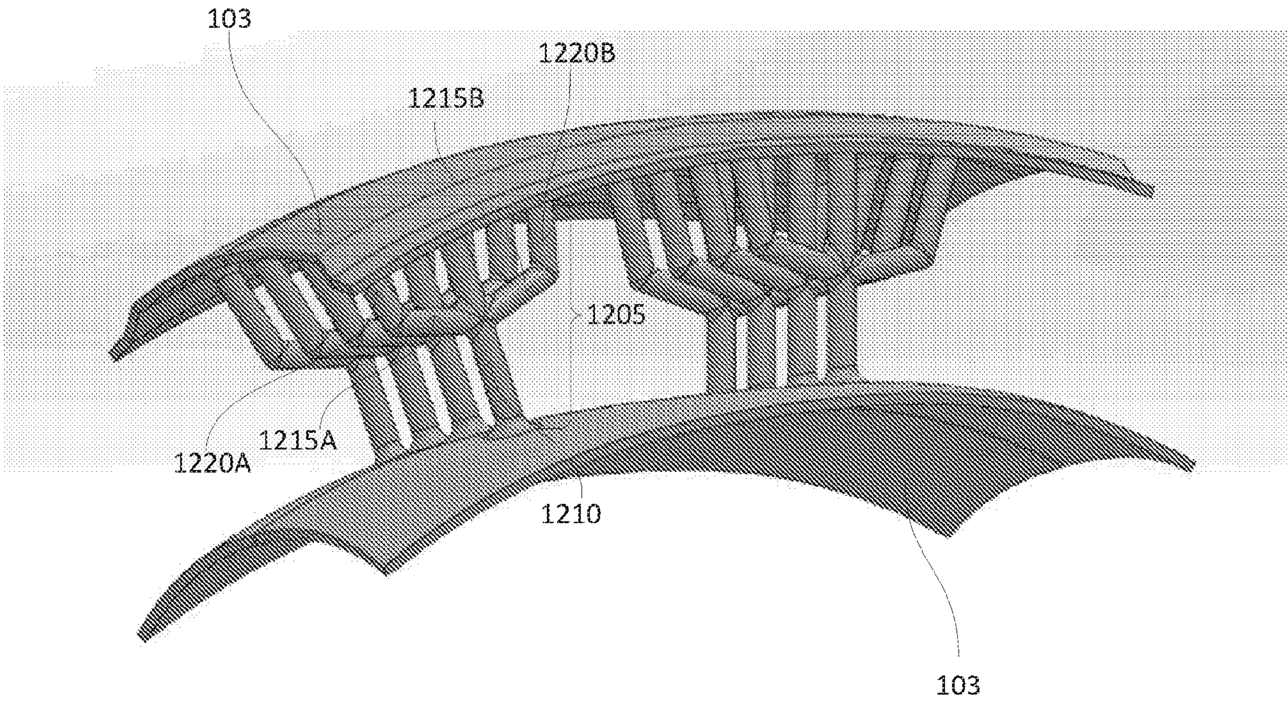
103
1220B
1215B
1205
1220A
1215A
1210
103

FIG. 12

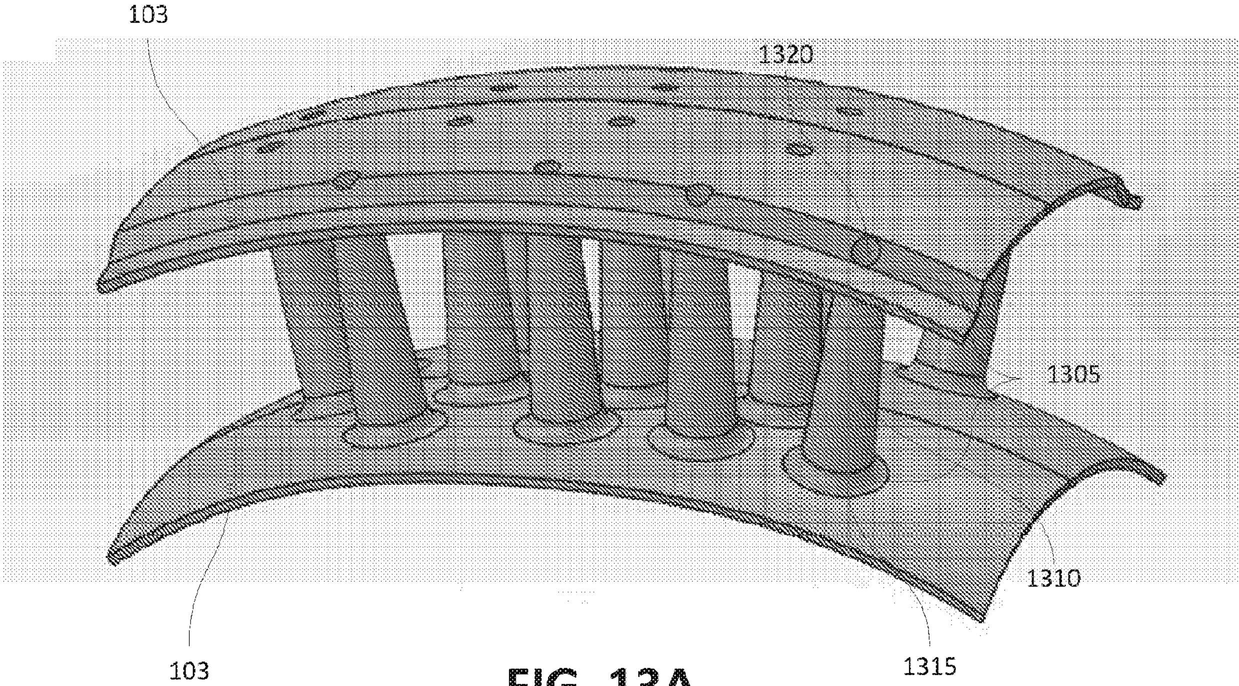

FIG. 13A

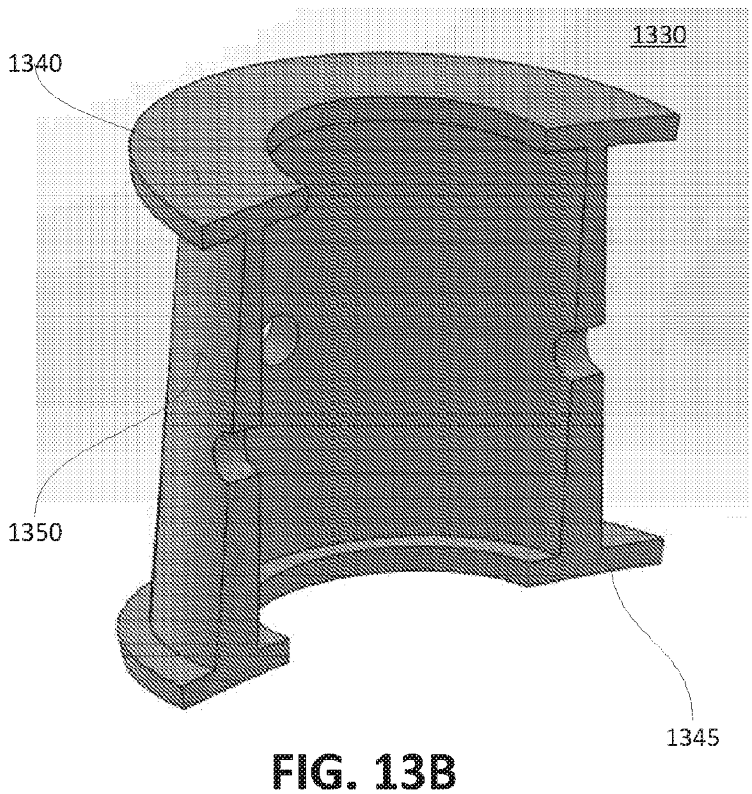

FIG. 13B

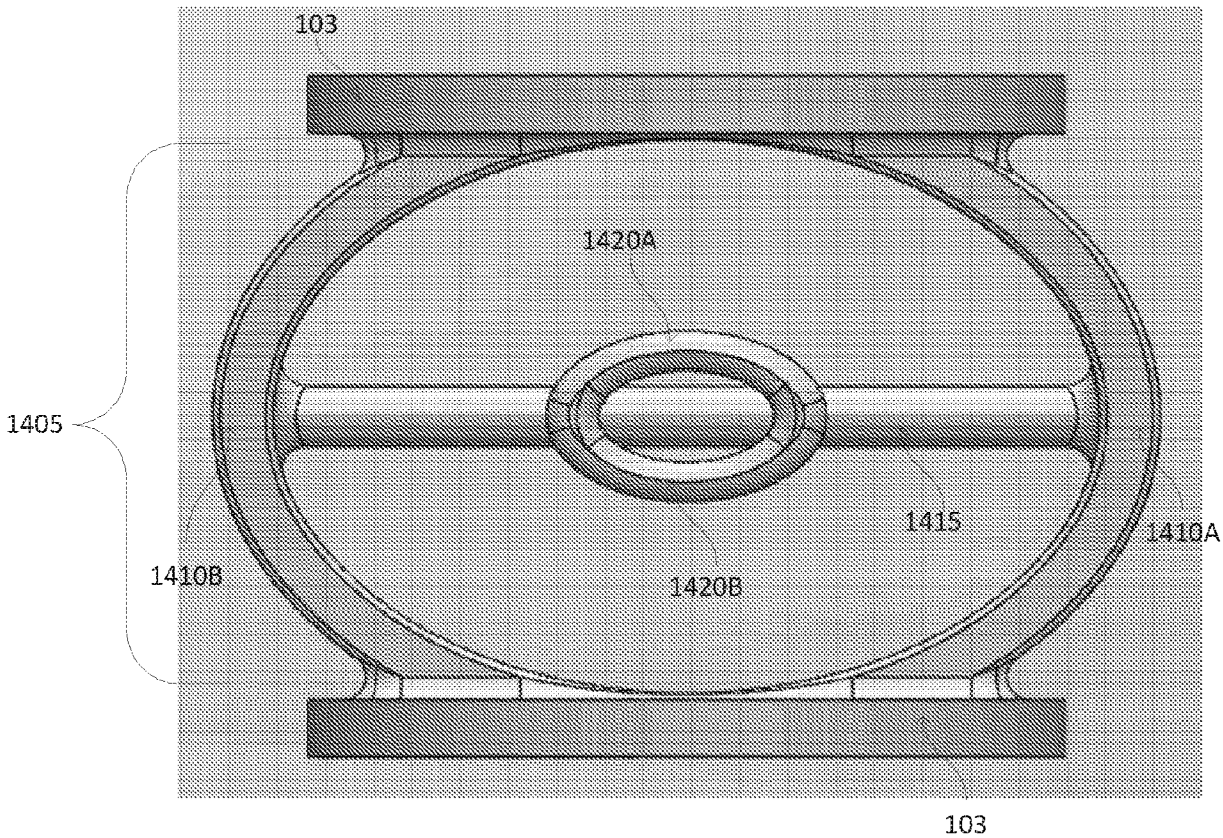
103
1420A
1405
1415
1410A
1410B
1420B
103

FIG. 14

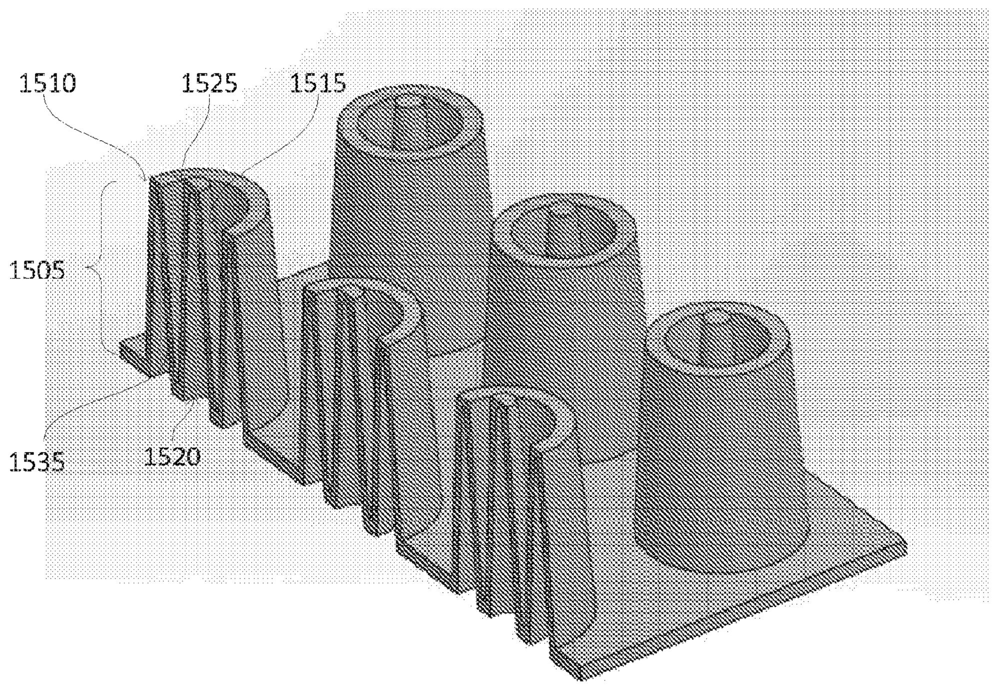
1510
1525
1515
1505
1535
1520

FIG. 15

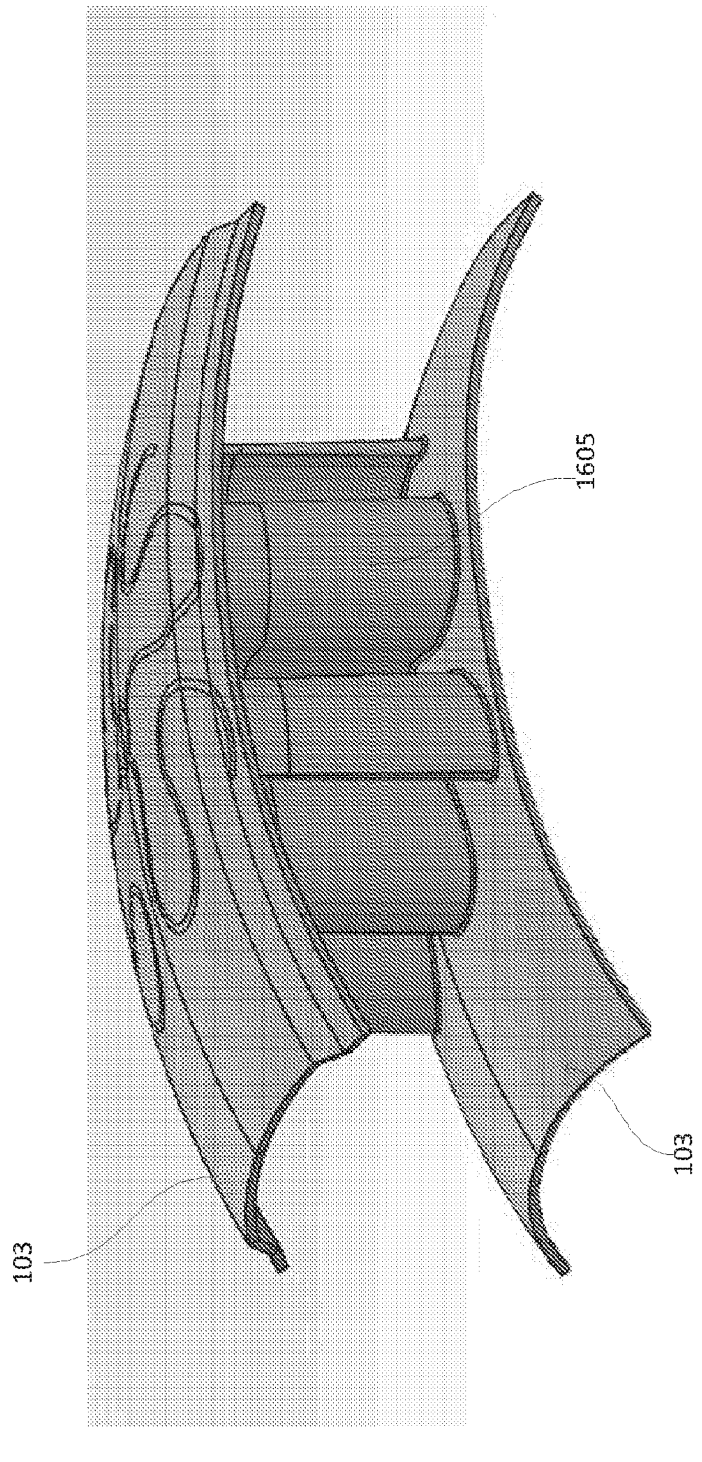

FIG. 16

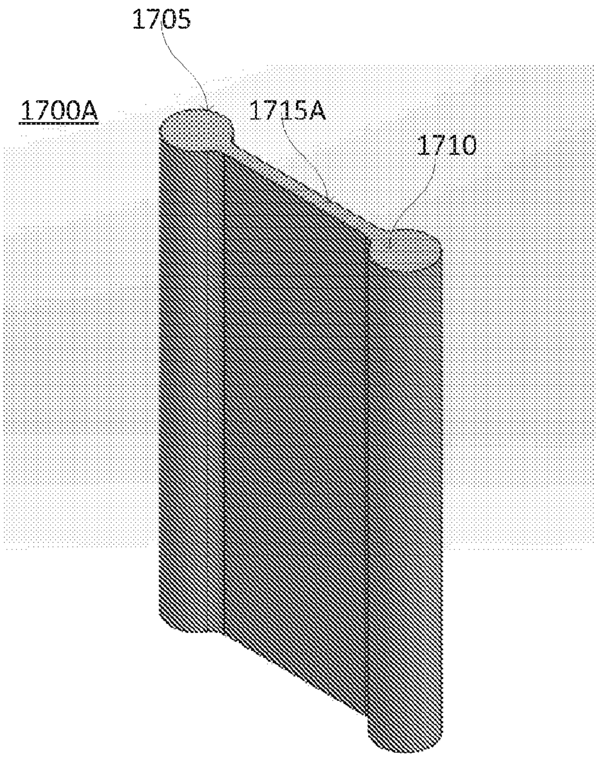

FIG. 17A

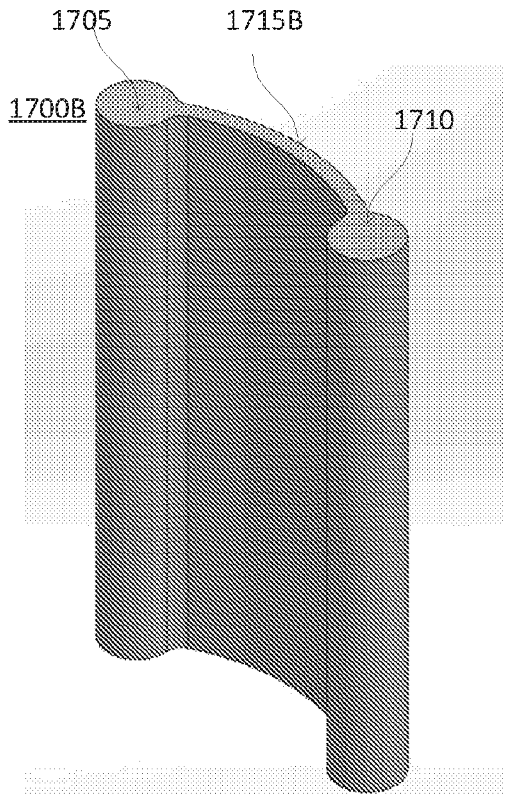

FIG. 17B

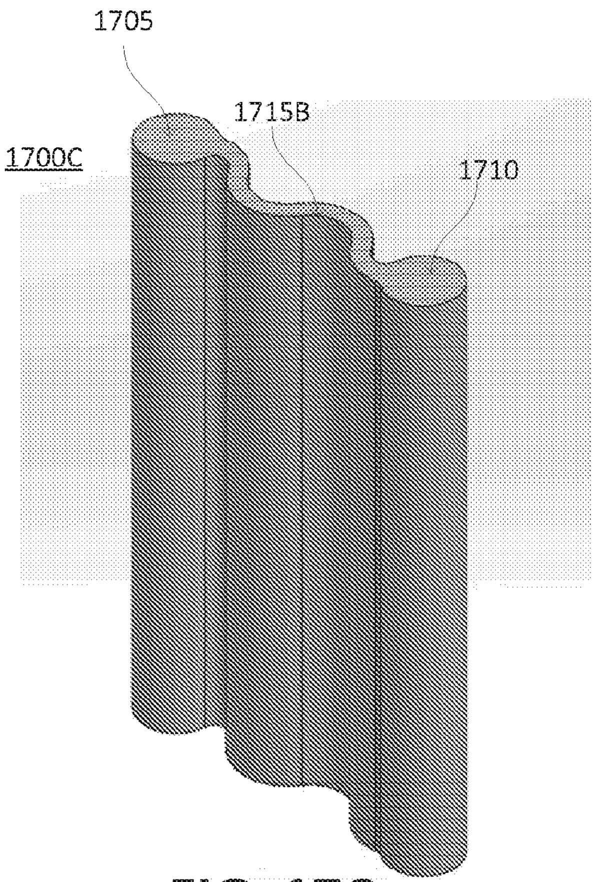

FIG. 17C

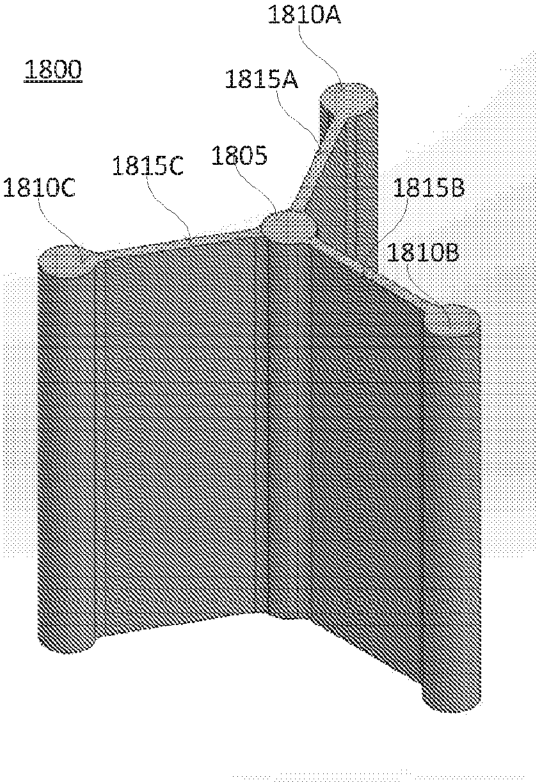

FIG. 18

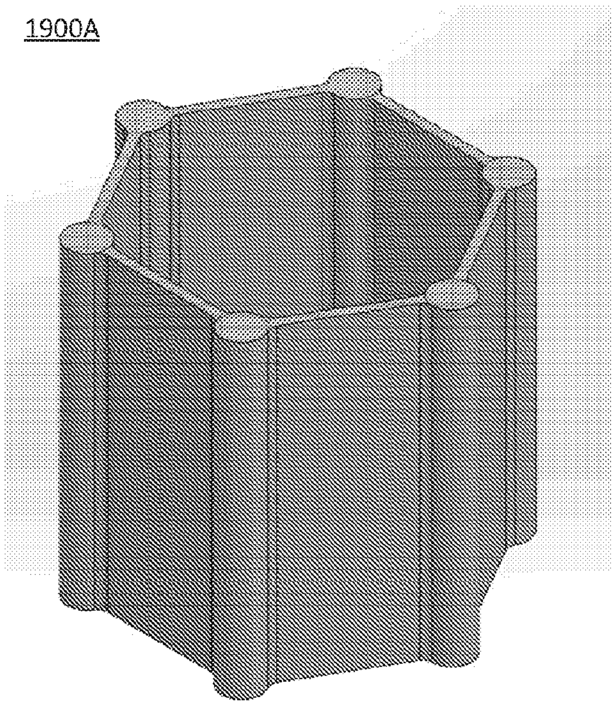

FIG. 19A

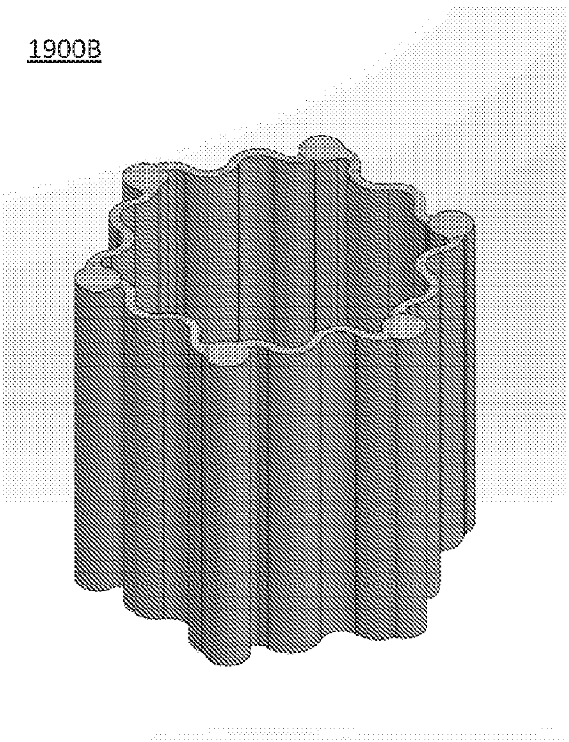

FIG. 19B

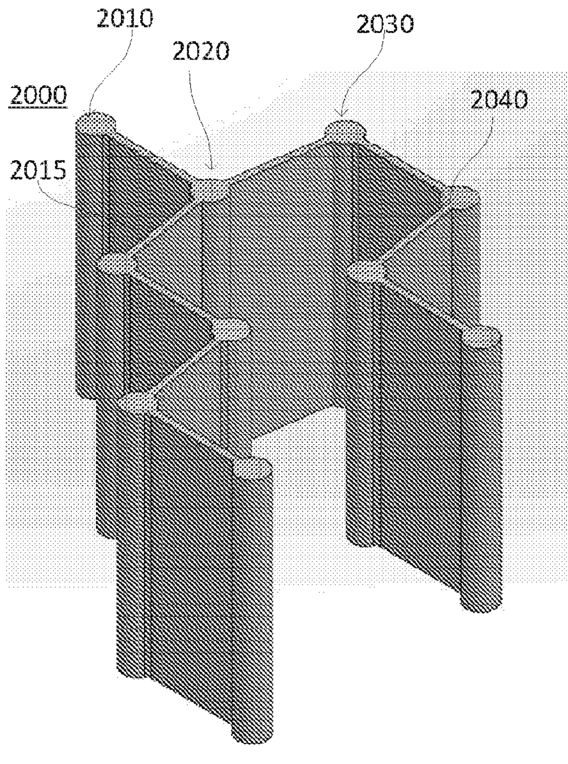

FIG. 20

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/012373

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A42B 3/12; A42B 3/00; A42B 3/04; A42B 3/06; A42B 3/10; A63B 71/10 (2017.01)

CPC - A42B 3/124; A42B 3/00; A42B 3/04; A42B 3/06; A42B 3/062; A42B 3/063; A42B 3/064; A42B 3/065; A42B 3/10; A42B 3/12; A42B 3/125; A42B 3/128; A63B 71/10 (2017.02)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 2/411; 2/412; 2/413; 2/414; 2/425 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2006/0070171 A1 (COPELAND et al) 06 April 2006 (06.04.2006) entire document	1, 9, 10, 13, 14 --- 2-8, 11, 12, 15-20
X --- Y	WO 2015/089646 A1 (BAUER HOCKEY CORP.) 25 June 2015 (25.06.2015) entire document	21-27 --- 28
Y	US 6,029,962 A (SHORTEN et al) 29 February 2000 (29.02.2000) entire document	2, 3
Y	US 2015/0285697 A1 (CHURCH HILL PUBLISHING, LLC) 08 October 2015 (08.10.2015) entire document	4-6, 17-19
Y	US 6,530,564 B1 (JULIEN) 11 March 2003 (11.03.2003) entire document	7
Y	US 7,516,597 B1 (ROOSE) 14 April 2009 (14.04.2009) entire document	8
Y	US 2015/0223547 A1 (ANGEL TECHNOLOGIES, LLC) 13 August 2015 (13.08.2015) entire document	11
Y	US 4,283,864 A (LIPFERT) 18 August 1981 (18.08.1981) entire document	12, 15, 16, 20
Y	US 6,969,548 B1 (GOLDFINE) 29 November 2005 (29.11.2005) entire document	28
A	US 4,412,358 A (LAVENDER) 01 November 1983 (01.11.1983) entire document	1-28

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 February 2017	17 MAR 2017

Name and mailing address of the ISA/US	Authorized officer
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/012373

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,204,998 A (LIU) 27 April 1993 (27.04.1993) entire document	1-28
A	US 2013/0185837 A1 (PHIPPS et al) 25 July 2013 (25.07.2013) entire document	1-28