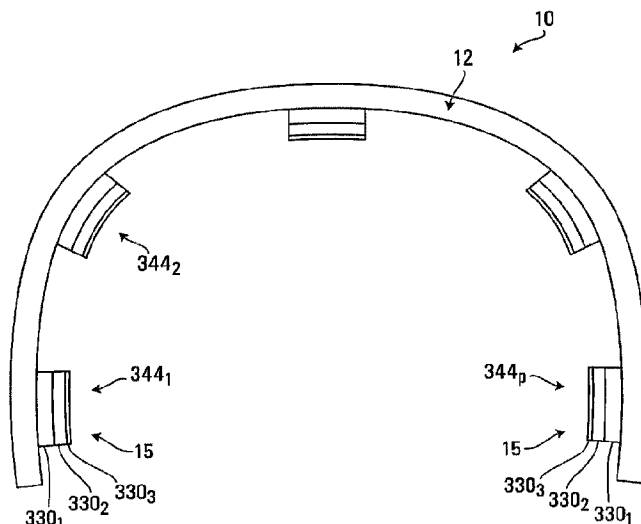




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A helmet for protecting a head of a wearer, such as a hockey, lacrosse, football or other sports player. The helmet comprising an outer shell and an inner padding disposed between the outer shell and the wearer's head when the helmet is worn. The inner padding comprising a plurality of shock absorbers and an interconnector interconnecting the shock absorbers, each shock absorber being deformable in response to a rotational impact on the helmet such that an outer part of the shock absorber moves relative to an inner part of the shock absorber in a direction tangential to an angular movement of the outer shell due to the rotational impact.



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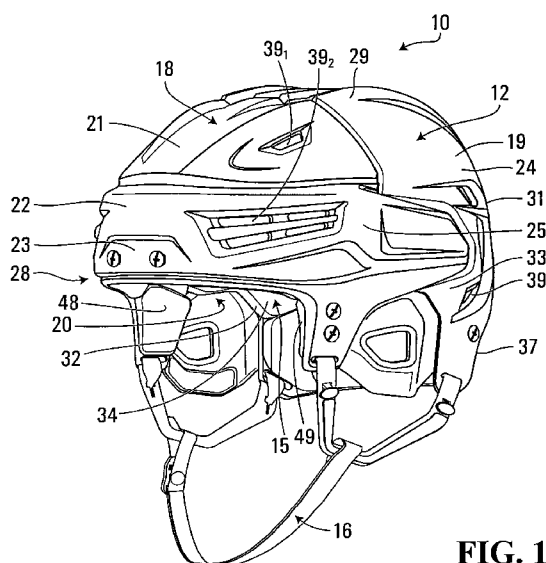


FIG. 1

(57) Abstract: A helmet for protecting a head of a wearer, such as a hockey, lacrosse, football or other sports player. The helmet comprising an outer shell and an inner padding disposed between the outer shell and the wearer's head when the helmet is worn. The inner padding comprising a plurality of shock absorbers and an interconnector interconnecting the shock absorbers, each shock absorber being deformable in response to a rotational impact on the helmet such that an outer part of the shock absorber moves relative to an inner part of the shock absorber in a direction tangential to an angular movement of the outer shell due to the rotational impact.

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HELMET FOR IMPACT PROTECTION

CROSS-REFERENCE TO RELATED APPLICATION

- 5 This application claims priority from U.S. Provisional Patent Application 61/918,092 filed on December 19, 2013.

FIELD

- 10 The invention relates generally to helmets and, more particularly, to helmets providing protection against impacts such as linear impacts and/or rotational impacts.

BACKGROUND

- 15 Helmets are worn in sports and other activities (e.g., motorcycling, industrial work, military activities, etc.) to protect their wearers against head injuries. To that end, helmets typically comprise a rigid outer shell and inner padding to absorb energy when impacted.

- Various types of impacts are possible. For example, a helmet may be subjected to a linear
20 impact in which an impact force is generally oriented to pass through a center of gravity of the wearer's head and imparts a linear acceleration to the wearer's head. A helmet may also be subjected to a rotational impact in which an impact force imparts an angular acceleration to the wearer's head. This can cause serious injuries such as concussions, subdural hemorrhage, or nerve damage.

- 25 Although helmets typically provide decent protection against linear impacts, their protection against rotational impacts is often deficient. This is clearly problematic given the severity of head injuries caused by rotational impacts.

- 30 Also, while various forms of protection against linear impacts have been developed, existing techniques may not always be adequate or optimal in some cases, such as for certain types of impacts (e.g., high- and low-energy impacts).

For these and other reasons, there is a need for improvements directed to providing helmets with enhanced impact protection.

SUMMARY OF THE INVENTION

5

According to various aspects of the invention, there is provided a helmet for protecting a head of a wearer, in which the helmet has any feature or combination of features disclosed herein.

10 For example, according to one aspect of the invention, there is provided a helmet for protecting a head of a wearer. The helmet comprises an outer shell and inner padding disposed between the outer shell and the wearer's head when the helmet is worn. The inner padding comprises a plurality of shock absorbers and an interconnector interconnecting the shock absorbers. Each shock absorber is deformable in response to a rotational impact on the
15 helmet such that an outer part of the shock absorber moves relative to an inner part of the shock absorber in a direction tangential to an angular movement of the outer shell due to the rotational impact.

According to another aspect of the invention, there is provided a helmet for protecting a head
20 of a wearer. The helmet comprises an outer shell and inner padding disposed between the outer shell and the wearer's head when the helmet is worn. The inner padding comprises: a plurality of shock absorbers, each shock absorber being deformable in response to an impact such that an outer part of the shock absorber moves relative to an inner part of the shock absorber; an interconnector interconnecting the shock absorbers; and a shearing layer
25 between the outer part of the shock absorber and the inner part of the shock absorber to allow the outer part of the shock absorber and the inner part of the shock absorber to shear relative to one another.

According to another aspect of the invention, there is provided a helmet for protecting a head
30 of a wearer. The helmet comprises an outer shell and inner padding disposed between the outer shell and the wearer's head when the helmet is worn. The inner padding comprises an arrangement of shock absorbers that is connected to another part of the helmet by a plurality of connectors which are deformable in response to a rotational impact on the helmet such that

the arrangement of shock absorbers moves relative to the outer shell in a direction tangential to an angular movement of the outer shell due to the rotational impact.

According to another aspect of the invention, there is provided a helmet for protecting a head
5 of a wearer. The helmet comprises a first protective layer and a second protective layer
meshing with the first protective layer. A meshing part of the first protective layer extends
into a meshing hollow space of the second protective layer and is movable relative to the
meshing hollow space of the second protective layer such that, in response to a rotational
10 impact on the helmet, the meshing part of the first protective layer moves relative to the
meshing hollow space of the second protective layer in a direction tangential to an angular
movement of an external surface of the helmet due to the rotational impact.

According to another aspect of the invention, there is provided a helmet for protecting a head
of a wearer. The helmet comprises an outer shell. The helmet comprises a shearable material
15 configured to elastically shear in response to a rotational impact on the helmet such that an
outer surface of the shearable material is movable relative to an inner surface of the shearable
material in a direction tangential to an angular movement of the outer shell due to the
rotational impact.

20 According to another aspect of the invention, there is provided a helmet for protecting a head
of a wearer. The helmet comprises an outer shell and inner padding disposed between the
outer shell and the wearer's head when the helmet is worn. The inner padding comprises a
plurality of padding layers that are stacked and interconnected such that compression of the
padding layers is decoupled from shearing of adjacent ones of the padding layers relative to
25 one another.

According to another aspect of the invention, there is provided a helmet for protecting a head
of a wearer. The helmet comprises an outer shell and inner padding disposed between the
outer shell and the wearer's head when the helmet is worn. The inner padding comprises a
30 plurality of pad members separate from one another. Each pad member comprises a plurality
of padding layers that are stacked and a connector interconnecting adjacent ones of the
padding layers such that compression of the padding layers is decoupled from shearing of the
adjacent ones of the padding layers relative to one another.

According to another aspect of the invention, there is provided a helmet for protecting a head of a wearer. The helmet comprises an outer shell and inner padding disposed between the outer shell and the wearer's head when the helmet is worn. The helmet comprises an impact deflector at an external side of the outer shell to deflect a rotational impact.

5

According to another aspect of the invention, there is provided a helmet for protecting a head of a wearer. The helmet comprises an outer shell and inner padding disposed between the outer shell and the wearer's head when the helmet is worn. The helmet comprises a sacrificial layer at an external side of the outer shell and configured to erode at a point of rotational impact.

10

According to another aspect of the invention, there is provided a helmet for protecting a head of a wearer. The helmet comprises an outer shell and inner padding disposed between the outer shell and the wearer's head when the helmet is worn. The helmet comprises a faceguard for protecting at least part of a face of the wearer. The faceguard is angularly movable relative to an internal surface of the helmet in response to a rotational impact on the faceguard.

15

According to another aspect of the invention, there is provided a helmet for protecting a head of a wearer. The helmet comprises: an external surface; an internal surface for contacting the wearer's head; and a rotational impact protection system for allowing an angular movement of the external surface relative to the internal surface in response to a rotational impact on the helmet. The rotational impact protection mechanism comprises a plurality of distinct rotational impact protection mechanisms to provide at least two levels of protection against the rotational impact.

20

25

According to another aspect of the invention, there is provided a helmet for protecting a head of a wearer. The helmet comprises an outer shell and inner padding connected to the outer shell. The inner padding is configured to be disposed between the outer shell and the
5 wearer's head. The inner padding comprises a plurality of pads separate from one another, each pad comprising a plurality of padding layers that overlap one another and are arranged such that adjacent ones of the padding layers of the pad are movable relative to one another in response to a rotational impact on the outer shell, wherein: the pad comprises a low-friction interface between the adjacent ones of the padding layers of the pad to facilitate
10 movement of the adjacent ones of the padding layers of the pad relative to one another; the low-friction interface of the pad is between a first one of the padding layers of the pad and a second one of the padding layers of the pad; and the low-friction interface of the pad is configured such that a coefficient of friction between the first one of the padding layers of the pad and the second one of the padding layers of the pad is lower than a coefficient of friction
15 between a shock-absorbing material of the first one of the padding layers of the pad and a shock-absorbing material of the second one of the padding layers of the pad.

According to another aspect of the invention, there is provided a helmet for protecting a head of a wearer. The helmet comprises an outer shell and inner padding connected to the outer
20 shell. The inner padding is configured to be disposed between the outer shell and the wearer's head. The inner padding comprises a plurality of pads separate from one another, each pad comprising a plurality of padding layers that overlap one another and are arranged such that adjacent ones of the padding layers of the pad are movable relative to one another in response to a rotational impact on the outer shell, wherein, for each pad of the plurality of
25 pads separate from one another, the plurality of padding layers of the pad comprises a comfort layer for contacting the wearer's head when the helmet is worn.

According to another aspect of the invention, there is provided a helmet for protecting a head of a wearer. The helmet comprises an outer shell and inner padding connected to the outer
30 shell. The inner padding is configured to be disposed between the outer shell and the wearer's head. The inner padding comprises a plurality of protective members separate from one another, each protective member comprising a plurality of layers that overlap one another and are arranged such that adjacent ones of the layers of the protective member are shearable

relative to one another and slidable against one another in response to a rotational impact on the outer shell.

According to another aspect of the invention, there is provided a helmet for protecting a head of a wearer. The helmet comprises an outer shell and inner padding configured to be disposed between the outer shell and the wearer's head. The inner padding comprises: i) an outer part connected to the outer shell; ii) an inner part that faces the wearer's head; and iii) a plurality of sliding interfaces separate from one another and arranged between the outer part and the inner part of the inner padding such that the outer part and the inner part of the inner padding are shearable relative to one another by sliding against one another in response to a rotational impact on the outer shell. In some embodiments, the inner part of the inner padding comprises a comfort layer for contacting the wearer's head when the helmet is worn. For example, in some embodiments, the comfort layer comprises a plurality of comfort pads separate from one another, the plurality of sliding interfaces separate from one another being arranged between the plurality of comfort pads and the outer part of the inner padding, such that each comfort pad of the plurality of comfort pads separate from one another is shearable relative to the outer part of the inner padding by sliding against the outer part of the inner padding in response to the rotational impact on the outer shell.

According to another aspect of the invention, there is provided a helmet for protecting a head of a wearer. The helmet comprises an outer shell, main shock absorption padding connected to the outer shell, and comfort padding configured to be arranged between the main shock absorption padding and the wearer's head when the helmet is worn. The comfort padding comprises a plurality of comfort pads for contacting the wearer's head when the helmet is worn, the comfort pads being separate from one another and separately connected to the main shock absorption padding such that each comfort pad is independently movable relative to the outer shell by sliding against the main shock absorption padding in response to a rotational impact on the outer shell.

These and other aspects of the invention will now become apparent to those of ordinary skill in the art upon review of the following description of embodiments of the invention in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

A detailed description of embodiments of the invention is provided below, by way of example only, with reference to the accompanying drawings, in which:

5

Figure 1 shows an example of a helmet for protecting a head of a wearer in accordance with an embodiment of the invention;

Figures 2 and 3 show a front and rear perspective view of the helmet;

10

Figures 4 to 8 show operation of an example of an adjustment mechanism of the helmet;

Figures 9 and 10 show the head of the wearer;

15

Figures 11 and 12 show examples of a faceguard that may be provided on the helmet;

Figure 13 shows internal dimensions of a head-receiving cavity of the helmet;

Figures 14 and 15 show an example of shell members of an outer shell of the helmet;

20

Figures 16 to 20 show an example of parts of inner padding of the helmet;

Figures 21 to 23 show an example of an arrangement of shock absorbers that are deformable;

25

Figures 24 to 27 show other examples of an arrangement of shock absorbers that are deformable;

Figure 28 shows an example of a shock absorber fastened to the outer shell;

30

Figures 29 to 31 and 34 show examples of a shock absorber having a frictional interface with the outer shell;

Figures 32 show an example of a shock absorber comprising a plurality of different deformable materials;

Figure 33 shows an example of a deformation of a shock absorber;

5

Figures 35 to 37 show an example of an arrangement of shock absorbers connected by connectors which are deformable;

Figures 38 and 39 show other examples of an arrangement of shock absorbers connected by connectors which are deformable;

10

Figures 40 and 41 show an example of a plurality of protective layers which are meshing with one another;

Figures 42 to 44 show other examples of a plurality of protective layers which are meshing with one another;

15

Figures 45 and 46 show an example of a shearable material part of the inner padding;

Figures 47 to 49 show another example of a shearable material part of the inner padding;

20

Figures 50 and 51 show an example of a shearable material forming an interface between the inner padding and the outer shell;

Figures 52 to 54 show an example of a floating liner;

25

Figure 55 shows an example of an impact deflector at an external side of the outer shell;

Figures 56 and 57 show an example of selected areas in which the impact deflector may be located;

30

Figures 58 and 59 show other examples of an impact deflector at an external side of the outer shell;

Figure 60 shows an example of a sacrificial layer at an external side of the outer shell;

5 Figure 61 shows an example of the faceguard being configured to provide rotational impact protection;

Figure 62 shows an example of a rotational impact protection system of the helmet comprising a plurality of distinct rotational impact protection mechanisms;

10 Figures 63 and 64 show other examples of the rotational impact protection system comprising a plurality of distinct rotational impact protection mechanisms;

Figures 65 to 72 show other examples of shock absorbers of the helmet;

15 Figures 73 to 77 show examples of padding layers that are stacked and interconnected such that compression of adjacent ones of the padding layers is decoupled from shearing of these adjacent ones of the padding layers relative to one another; and

20 Figure 78 to 84 show examples of an arrangement of shock absorbers in which a shearing layer facilitates shearing of different parts of the shock absorbers relative to one another.

It is to be expressly understood that the description and drawings are only for the purpose of illustrating certain embodiments of the invention and are an aid for understanding. They are not intended to be a definition of the limits of the invention.

25

DETAILED DESCRIPTION OF EMBODIMENTS

Figures 1 to 8 show an example of a helmet 10 for protecting a head 11 of a wearer in accordance with an embodiment of the invention. In this embodiment, the helmet 10 is a sports helmet for protecting the head 11 of the wearer who is a sports player. More particularly, in this embodiment, the helmet 10 is a hockey helmet for protecting the head 11 of the wearer who is a hockey player. In other embodiments, the helmet 10 may be any other type of helmet for other sports (e.g., lacrosse, football, baseball, bicycling, skiing,

snowboarding, horseback riding, etc.) and activities other than sports (e.g., motorcycling, industrial applications, military applications, etc.) in which protection against head injury is desired.

5 The helmet 10 defines a cavity 13 for receiving the wearer's head 11 to protect the wearer's head 11 when the helmet 10 is impacted (e.g., when the helmet 10 hits a board or an ice or other skating surface of a hockey rink or is struck by a puck or a hockey stick). In this embodiment, the helmet 10 is designed to provide protection against various types of impacts. More particularly, in this embodiment, the helmet 10 is designed to provide
10 protection against a linear impact in which an impact force is generally oriented to pass through a center of gravity of the wearer's head 11 and imparts a linear acceleration to the wearer's head 11. In addition, in this embodiment, the helmet 10 is designed to provide protection against a rotational impact in which an impact force imparts an angular acceleration to the wearer's head 11.

15 In response to an impact, the helmet 10 absorbs energy from the impact to protect the wearer's head 11. Notably, in this embodiment, in order to provide protection against rotational impacts, the helmet 10 comprises a rotational impact protection system 28 responsive to a rotational impact to absorb rotational energy from the rotational impact. This
20 reduces rotational energy transmitted to the wearer's head 11 and therefore reduces an angular acceleration of the wearer's 11.

The helmet 10 protects various regions of the wearer's head 11. As shown in Figures 9 and 10, the wearer's head 11 comprises a front region FR, a top region TR, left and right side
25 regions LS, RS, a back region BR, and an occipital region OR. The front region FR includes a forehead and a front top part of the head 11 and generally corresponds to a frontal bone region of the head 11. The left and right side regions LS, RS are approximately located above the wearer's ears. The back region BR is opposite the front region FR and includes a rear upper part of the head 11. The occipital region OR substantially corresponds to a region
30 around and under the head's occipital protuberance.

The helmet 10 comprises an external surface 18 and an internal surface 20 that contacts the wearer's head 11 when the helmet 10 is worn. The helmet 10 has a front-back axis FBA, a

left-right axis LRA, and a vertical axis VA which are respectively generally parallel to a dorsoventral axis, a dextrosinistral axis, and a cephalocaudal axis of the wearer when the helmet 10 is worn and which respectively define a front-back direction, a left-right direction, and a vertical direction of the helmet 10. Since they are generally oriented longitudinally and transversally of the helmet 10, the front-back axis FBA and the left-right axis LRA can also be referred to as a longitudinal axis and a transversal axis, respectively, while the front-back direction and the left-right direction can also be referred to a longitudinal direction and a transversal direction.

- 10 In this embodiment, the helmet 10 comprises an outer shell 12 and inner padding 15. The helmet 10 also comprises a chinstrap 16 for securing the helmet 10 to the wearer's head 11. As shown in Figures 11 and 12, the helmet 10 may also comprise a faceguard 14.

- 15 The outer shell 12 provides strength and rigidity to the hockey helmet 10. To that end, the outer shell 12 is made of rigid material. For example, in various embodiments, the outer shell 12 may be made of thermoplastic material such as polyethylene, polyamide (nylon), or polycarbonate, of thermosetting resin, or of any other suitable material. The outer shell 12 has an inner surface 17 facing the inner padding 15 and an outer surface 19 opposite the inner surface 17. The outer surface 19 of the outer shell 12 constitutes at least part of the external surface 18 of the helmet 10.

- 20 In this embodiment, the outer shell 12 comprises a front outer shell member 22 and a rear outer shell member 24 that are connected to one another. The front outer shell member 22 comprises a top portion 21 for facing at least part of the top region TR of the wearer's head 11, a front portion 23 for facing at least part of the front region FR of the wearer's head 11, and left and right lateral side portions 25, 27 extending rearwardly from the front portion 23 for facing at least part of the left and right side regions LS, RS of the wearer's head 11. The rear outer shell member 24 comprises a top portion 29 for facing at least part of the top region TR of the wearer's head 11, a back portion 31 for facing at least part of the back region BR of the wearer's head 11, an occipital portion 37 for facing at least part of the occipital region OR of the wearer's head 11, and left and right lateral side portions 33, 35 extending forwardly from the back portion 31 for facing at least part of the left and right side regions LS, RS of the wearer's head 11.

In this embodiment, the helmet 10 is adjustable to adjust how it fits on the wearer's head 11. To that end, the helmet 10 comprises an adjustment mechanism 40 for adjusting a fit of the helmet 10 on the wearer's head 11. The adjustment mechanism 40 allows the fit of the helmet
5 10 to be adjusted by adjusting one or more internal dimensions of the cavity 13 of the helmet 10, such as a front-back internal dimension FBD of the cavity 13 in the front-back direction of the helmet 10 and/or a left-right internal dimension LRD of the cavity 13 in the left-right direction of the helmet 10, as shown in Figure 13.

10 More particularly, in this embodiment, the outer shell 12 and the inner padding 15 are adjustable to adjust the fit of the helmet 10 on the wearer's head 11. To that end, in this case, the front outer shell member 22 and the rear outer shell member 24 are movable relative to one another to adjust the fit of the helmet 10 on the wearer's head 11. The adjustment
15 mechanism 40 is connected between the front outer shell member 22 and the rear outer shell member 24 to enable adjustment of the fit of the helmet 10 by moving the outer shell members 22, 24 relative to one another. In this example, relative movement of the outer shell members 22, 24 for adjustment purposes is in the front-back direction of the helmet 10 such that the front-back internal dimension FBD of the cavity 13 of the helmet 10 is adjusted. This
20 is shown in Figures 5 to 8 in which the rear outer shell member 24 is moved relative to the front outer shell member 22 from a first position, which is shown in Figure 5 and which corresponds to a relatively small size of the helmet 10, to a second position, which is shown in Figure 6 and which corresponds to an intermediate size of the helmet 10, and to a third
position, which is shown in Figures 7 and 8 and which corresponds to a relatively large size of the helmet 10.

25 In this example of implementation, the adjustment mechanism 40 comprises an actuator 41 that can be moved (in this case pivoted) by the wearer between a locked position, in which the actuator 41 engages a locking part 45 (as best shown in Figures 14 and 15) of the front outer shell member 22 and thereby locks the outer shell members 22, 24 relative to one
30 another, and a release position, in which the actuator 41 is disengaged from the locking part 45 of the front outer shell member 22 and thereby permits the outer shell members 22, 24 to move relative to one another so as to adjust the size of the helmet 10. The adjustment mechanism 40 may be implemented in various other ways in other embodiments.

In this embodiment, the outer shell 12 comprises a plurality of ventilation holes 39₁-39_V allowing air to circulate around the wearer's head 11 for added comfort. In this case, each of the front and rear outer shell members 22, 24 defines respective ones of the ventilation holes
5 39₁-39_V of the outer shell 12.

The outer shell 12 may be implemented in various other ways in other embodiments. For example, in other embodiments, the outer shell 12 may be a single-piece shell. In such embodiments, the adjustment mechanism 40 may comprise an internal adjustment device
10 located within the helmet 10 and having a head-facing surface movable relative to the wearer's head 11 in order to adjust the fit of the helmet 10. For instance, in some cases, the internal adjustment device may comprise an internal pad member movable relative to the wearer's head 11 or an inflatable member which can be inflated so that its surface can be moved closer to or further from the wearer's head 11 to adjust the fit.

15 The inner padding 15 is disposed between the outer shell 12 and the wearer's head 11 in use to absorb impact energy when the helmet 10 is impacted. More particularly, the inner padding 15 comprises a shock-absorbing structure 32 that includes an outer surface 38 facing towards the outer shell 12 and an inner surface 34 facing towards the wearer's head 11. For
20 example, in some embodiments, the shock-absorbing structure 32 of the inner padding 15 may comprise a shock-absorbing material. For instance, in some cases, the shock-absorbing material may include a polymeric cellular material, such as a polymeric foam (e.g., expanded polypropylene (EPP) foam, expanded polyethylene (EPE) foam, vinyl nitrile (VN) foam, polyurethane foam (e.g., PORON XRD foam commercialized by Rogers Corporation), or any
25 other suitable polymeric foam material), or expanded polymeric microspheres (e.g., Expancel™ microspheres commercialized by Akzo Nobel). In some cases, the shock-absorbing material may include an elastomeric material (e.g., a rubber such as styrene-butadiene rubber or any other suitable rubber; a polyurethane elastomer such as thermoplastic polyurethane (TPU); any other thermoplastic elastomer; etc.). In some cases, the shock-
30 absorbing material may include a fluid (e.g., a liquid or a gas), which may be contained within a container (e.g., a flexible bag, pouch or other envelope) or implemented as a gel (e.g., a polyurethane gel). Any other material with suitable impact energy absorption may be used in other embodiments. Additionally or alternatively, in some embodiments, the shock-

absorbing structure 32 of the inner padding 15 may comprise an arrangement (e.g., an array) of shock absorbers that are configured to deform when the helmet 10 is impacted. For instance, in some cases, the arrangement of shock absorbers may include an array of compressible cells that can compress when the helmet 10 is impacted. Examples of this are
 5 described in U.S. Patent 7,677,538 and U.S. Patent Application Publication 2010/0258988.

The inner padding 15 may be mounted to the outer shell 12 in various ways. For example, in some embodiments, the inner padding 15 may be mounted to the outer shell 12 by one or more fasteners such as mechanical fasteners (e.g., tacks, staples, rivets, screws, stitches, etc.),
 10 an adhesive, or any other suitable fastener. In such embodiments, the inner padding 15 is affixed to the outer shell 12 and, during movement of the front and rear outer shell members 22, 24 to adjust the size of the helmet 10, various parts of the inner padding 15 move along with the outer shell members 22, 24.

15 In this embodiment, as shown in Figures 16 to 20, the inner padding 15 comprises a front left inner pad member 52 for facing at least part of the front region FR and left side region LS of the wearer's head 11, a front right inner pad member 51 for facing at least part of the front region FR and right side region RS of the wearer's head 11, a rear left inner pad member 56 for facing at least part of the back region BR and left side region LS of the wearer's head 11,
 20 a rear right inner pad member 54 for facing at least part of the back region BR and right side region RS of the wearer's head 11, and a top inner pad member 58 for facing at least part of the top region TR and back region BR of the wearer's head 11. The front outer shell member 22 overlays the front right and left inner pad members 51, 52 while the rear outer shell member 24 overlays the rear right and left inner pad members 54, 56 and the top inner pad member 58. The inner pad members 51, 52, 54, 56, 58 of the inner padding 15 are movable
 25 relative to one another and with the outer shell members 22, 24 to allow adjustment of the fit of the helmet 10 using the adjustment mechanism 40.

Also, in this embodiment, the inner padding 15 comprises left and right comfort pad members 48, 49 for facing the left and right side regions of the wearer's head 11 above the
 30 ears. The comfort pad members 48, 49 may comprise any suitable soft material providing comfort to the wearer. For example, in some embodiments, the comfort pad members 48, 49

may comprise polymeric foam such as polyvinyl chloride (PVC) foam or polyurethane foam (e.g., PORON XRD foam commercialized by Rogers Corporation).

5 The inner padding 15 may be implemented in various other ways in other embodiments. For example, in other embodiments, the inner padding 15 may comprise any number of pad members (e.g., two pad members such as one pad member that faces at least part of the front region FR, top region TR, and left and right side regions LS, RS of the wearer's head 11 and another pad member that faces at least part of the back region BR, top region TR, and left and right side regions LS, RS of the wearer's head 11; a single pad that faces at least part of the front region FR, top region TR, left and right side regions LS, RS, and back region BR of the
10 wearer's head 11; etc.).

The faceguard 14, when part of the helmet 10, protects at least part of a face of the wearer. For example, in some embodiments, as shown in Figure 12, the faceguard 14 may comprise a
15 grid (sometimes referred to as a "cage"). As another example, in some embodiments, as shown in Figure 11, the faceguard 14 may comprise a visor (sometimes referred to as a "shield"). The visor may cover the wearer's eyes, nose and mouth or may cover a smaller area of the wearer's face (e.g., the wearer's eyes but not his/her nose and mouth).

20 The rotational impact protection system 28 of the helmet 10 may be implemented in various ways. Examples of embodiments of the rotational impact protection system 28 are considered below.

1. Internal elements for rotational impact protection

25 In some embodiments, the rotational impact protection system 28 of the helmet 10 may comprise one or more internal elements (e.g., of the outer shell 12 and/or the inner padding 15) movable relative to one another or otherwise configured to absorb energy from a rotational impact.

30

1.1 Arrangement of shock absorbers which are deformable in response to a rotational impact

In some embodiments, as shown in Figures 21 to 23, the shock-absorbing structure 32 of the inner padding 15 may comprise an arrangement (e.g., an array) of shock absorbers 65₁-65_N which are deformable (e.g., shearable or deflectable) in response to a rotational impact on the helmet 10, such that an outer part 66 of a given one of the shock absorbers 65₁-65_N moves relative to an inner part 67 of the given one of the shock absorbers 65₁-65_N in a direction tangential to an angular movement of the outer shell 12 due to the rotational impact. This elastic deformation of the shock absorbers 65₁-65_N absorbs energy from the rotational impact and may thus reduce its effect on the wearer's head 11.

In this embodiment, the shock-absorbing structure 32 of the inner padding 15 comprises an interconnector 68 interconnecting the shock absorbers 65₁-65_N such that the shock absorbers 65₁-65_N are linked together as a group. For instance, in this embodiment, the interconnector 68 comprises a base 69 from which project the shock absorbers 65₁-65_N. The interconnector 68 may comprise a liner 71 for contacting the wearer's head 11. By way of example, the liner 71 may comprise foam for comfort of the wearer's head 11 such as polyvinyl chloride (PVC) foam or polyurethane foam (e.g., PORON XRD foam commercialized by Rogers Corporation).

More particularly, in this embodiment, each shock absorber 65_x is a compressible cell that can compress in response to a linear impact force. For instance, the shock absorber 65_x may include a tubular member 62_x. In this case, the tubular member 62_x may have an elongated shape with a top opening 63, a bottom opening 64, and a passageway 61 extending through it. The tubular members 62-62_N may be arranged in any suitable configuration, such as in a staggered configuration as shown in Figure 22, as in a square matrix as shown in Figure 24, or in any other desired configuration. The tubular members 62-62_N may have any other suitable shape in other embodiments (e.g., the cross-sectional dimensions of the tubular member 62_x along its length from the top opening 63 to the bottom opening 64 may vary). In some examples of implementation, the tubular members could be implemented using the structure discussed in U.S. Patent 7,677,538 and U.S. Patent Application Publication 2010/0258988.

Each shock absorber 65_x is configured such that the angular movement of the outer shell 12 due to a rotational impact causes the outer part 66 of the each shock absorber 65_x to move relative to the inner part 67 of the shock absorber 65_x in a direction tangential to the outer shell's angular movement. In this case, the outer part 66 of the shock absorber 65_x interfaces with the outer shell 12 such that the outer part 66 is dragged or otherwise drawn by the outer shell 12 when the outer shell 12 angularly moves. For instance, the embodiment shown in Figure 23 illustrates in dotted lines the outer part 66 of each shock absorber 65_x displaced relative to the inner part 67 of each shock absorber 65_x in a direction tangential to the outer shell's angular movement. For example, with additional reference to Figure 28, in some embodiments, the outer part 66 of the shock absorber 65_x may be fastened to the outer shell 12 by a fastener 72. In various cases, the fastener 72 may be an adhesive fastener, a mechanical fastener (e.g., screw or other threaded fastener, rivet, etc.) or any other suitable fastener.

Each shock absorber 65_x is at least partly (i.e., partly or entirely) made of a deformable material 75 to allow it to elastically deform such that the outer part 66 of the shock absorber 65_x moves relative to the inner part 67 of the shock absorber 65_x in a direction tangential to the outer shell's angular movement. In that sense, the deformable material 75 may sometimes be referred to as a "flexible", "elastic", "compliant" or "resilient" material. For instance, in some embodiments, the deformable material 75 of the shock absorber 65_x is such that the shock absorber 65_x is shearable. In some embodiments, the deformable material 75 of the shock absorber 65_x is such that the shock absorber 65_x is bendable. In some embodiments, the deformable material 75 of the shock absorber 65_x is such that the shock absorber 65_x is stretchable.

For example, in some embodiments, the deformable material 75 may have an elastic modulus (i.e., modulus of elasticity) of no more than a certain value to provide suitable elastic deformation. For instance, in some embodiments, the elastic modulus of the deformable material 75 may be no more than 75 MPa, in some cases no more than 65 MPa, in some cases no more than 55 MPa, in some cases less than 45 MPa, and in some cases even less. The elastic modulus of the deformable material 75 may have any other suitable value in other embodiments.

As another example, in some embodiments, the deformable material 75 may have a resilience within a certain range to provide suitable elastic deformation. For instance, in some embodiments, the resilience of the deformable material 75 may be at least 10%, in some cases at least 20%, in some cases at least 30%, and in some cases at least 40% according to DIN 53512 of the German institute for standardization and/or may be no more than 40%, in some cases no more than 30%, in some cases no more than 20%, and in some cases no more than 10% according to DIN 53512. The resilience of the deformable material 75 may have any other suitable value in other embodiments.

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As another example, in some embodiments, the deformable material 75 may have a compression deflection within a certain range to provide suitable elastic deformation. For instance, in some embodiments, the compression deflection (i.e., 25% compression deflection) of the deformable material 75 may be at least 5 psi, in some cases at least 10 psi, in some cases at least 20 psi, and in some cases at least 30 psi according to ASTM D-1056 and/or may be no more than 30 psi, in some cases no more than 20 psi, in some cases no more than 10 psi, and in some cases no more than 5 psi according to ASTM D-1056. The compression deflection of the deformable material 75 may have any other suitable value in other embodiments.

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For instance, in some embodiments, the deformable material 75 may comprise polymeric cellular material. For instance, the polymeric cellular material may comprise polymeric foam such as expanded polypropylene (EPP) foam, expanded polyethylene (EPE) foam, vinyl nitrile (VN) foam, polyurethane foam (e.g., PORON XRD foam commercialized by Rogers Corporation), or any other suitable polymeric foam material and/or may comprise expanded polymeric microspheres (e.g., ExpancelTM microspheres commercialized by Akzo Nobel). In other embodiments, the deformable material 75 may comprise an elastomeric material (e.g., a rubber such as styrene-butadiene rubber or any other suitable rubber; a polyurethane elastomer such as thermoplastic polyurethane (TPU); any other thermoplastic elastomer; etc.). In yet other embodiments, the deformable material 75 may comprise a flexible plastic (e.g., low-density polyethylene).

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In order to provide rotational impact protection, in some embodiments, each shock absorber 65_x may have a shear stiffness K_s of no more than a certain value, where the shear stiffness K_s is defined as a ratio F_s/δ_s of a shear force F_s applied at an outer end 78 of the shock absorber 65_x over a displacement δ_s of the outer end 78 of the shock absorber 65_x while an inner end 5 79 of the shock absorber 65_x is fixed, as shown in Figure 31.

The shock absorbers 65₁-65_N and/or the interconnector 68 may be manufactured using any suitable manufacturing technique. For example, in some embodiments, the shock absorbers 65₁-65_N may be made by molding (e.g., injection molding), such as by integrally molding 10 them together as one-piece or molding them as separate parts and then assembled together (e.g., by an adhesive, ultrasonic welding, stitching, etc.), or may be made by any other suitable manufacturing process.

The arrangement of shock absorbers 65₁-65_N and the interconnector 68 may be configured in 15 various other ways in other embodiments.

For example, in other embodiments, as shown in Figures 25 to 27, the interconnector 68 may comprise interconnecting members 70₁-70_M between the shock absorbers 65₁-65_N, with or without the base 69. For instance, the interconnecting members 70₁-70_M may be webs 20 constituting webbing. Furthermore, the webs 70₁-70_M may be configured for maintaining the axis of elongation of each of the shock absorbers 65₁-65_N. For example, Figure 25 and Figures 26 and 27 illustrate the shock absorbers 65₁-65_N interconnected with the webs 70₁-70_M in a triangular and square configuration, respectively. In some cases, the interconnecting members 70₁-70_M may be web members similar to what is discussed in U.S. Patent 7,677,538 25 and U.S. Patent Application Publication 2010/0258988.

By way of another example, in other embodiments, as shown in Figures 29 to 31, the outer part 66 of the shock absorber 65_x may have a frictional interface 80 with the outer shell 12 to frictionally engage the outer shell 12 with sufficient friction that the outer part 66 is dragged 30 or otherwise drawn by the outer shell 12 when the outer shell 12 angularly moves. For instance, in some embodiments, a coefficient of friction between the outer shell 12 and the outer part 66 of the shock absorber 65_x may be at least 0.2, in some cases at least 0.3, in some cases at least 0.4, in some cases at least 0.5, in some cases at least 0.6, in some cases at least

0.7, and in some cases even more, according to ASTM G115. The coefficient of friction between the outer shell 12 and the outer part 66 of the shock absorber 65_x may have any other suitable value in other embodiments.

- 5 For instance, in some embodiments, as shown in Figures 30 and 31, the frictional interface 80 may comprise an arrangement of friction-increasing members 73₁-73_F on the inner surface 17 of outer shell 12 and/or the outer part 66 of the shock absorber 65_x. More specifically, the friction-increasing members 73₁-73_F may comprise: recesses (e.g., grooves) and/or projections (e.g., ridges); a corrugated surface; textured surface with “rough” surface texture;
- 10 or a combination thereof. The friction-increasing members 73₁-73_F may be on the inner surface 17 of outer shell 12, on the outer part 66 of the shock absorber 65_x, or on both.

- In other embodiments, as illustrated in Figure 34, the frictional interface 80 may comprise a tackifying material 81 to exert sufficient friction to draw or drag the outer part 66 of the shock absorber 65_x when the outer shell 12 angularly moves. For instance, the tackifying
- 15 material 81 may comprise a thermoplastic elastomer (e.g., Santoprene™), polyurethane (thermoplastic or thermoset), polyvinyl chloride (e.g., Plastisol), silicone, or any other suitable material providing tackiness.

- 20 In embodiments where individual ones of the shock absorbers 65₁-65_N are not directly connected or fastened to the outer shell 12, the arrangement of shock absorbers 65₁-65_N may be secured within the helmet 10 in any suitable way. For example, in some embodiments, the interconnector 68 may be fastened to the outer shell 12 at one or more fastening points along a lower edge portion of the outer shell 12 by one or more fasteners (e.g., screws, rivets, an
- 25 adhesive, etc.).

- By way of another example, in some embodiments, different parts of the shock absorber 65_x may be configured to exhibit different levels of stiffness such that a first part of the shock absorber 65_x is stiffer than a second part of the shock absorber 65_x, thereby resulting in the
- 30 first part of the shock absorber 65_x deforming less than the second part of the shock absorber 65_x in response to an impact.

For example, in some embodiments, with additional reference to Figure 32, different parts of the shock absorber 65_x may be made of different deformable materials such that a first part of the shock absorber 65_x is made of the deformable material 75 and a second part of the shock absorber 65_x is made of a deformable material 77 different from (e.g., stiffer than) the deformable material 75. For instance, in this case, the outer part 66 of the shock absorber 65_x may be made of the deformable material 75 and the inner part 67 of the shock absorber 65_x may be made of the deformable material 77 which is stiffer (e.g., denser) than the deformable material 75 such that the outer part 66 deforms more than the inner part 67. In other cases, this may be reversed, with the deformable material 75 being stiffer (e.g., denser) than the deformable material 77.

As another example, in some embodiments, with additional reference to Figures 65 and 66, different parts of the shock absorber 65_x may have different shapes (e.g., different sizes and/or different geometries) such that a shape of a first part of the shock absorber 65_x is different from a shape of a second part of the shock absorber 65_x and makes the first part of the shock absorber 65_x more rigid than the second part of the shock absorber 65_x. For instance, in this case, a shape of the inner part 67 of the shock absorber 65_x may be different than a shape of the outer part 66 of the shock absorber 65_x and make the inner part 67 of the shock absorber 65_x more rigid than the outer part 66 of the shock absorber 65_x such that the outer part 66 deforms more than the inner part 67. In this example, a cross-sectional dimension (e.g., a diameter) of the inner part 67 of the shock absorber 65_x may be than that of the outer part 66 of the shock absorber 65_x, thereby making it more rigid. More particularly, in this example, the inner part 67 and the outer part 66 of the shock absorber 65_x may be cylindrical with the inner part 67 having a greater outer diameter than the outer part 66. In other examples, this may be reversed, with the inner part 67 of the shock absorber 65_x being smaller and less rigid than the outer part 66 of the shock absorber 65_x. The inner part 67 and the outer part 66 of the shock absorber 65_x may have any other suitable different shapes in other examples (e.g., polygonal and non-polygonal shapes).

As another example, in some embodiments, with additional reference to Figure 67, different parts of the shock absorber 65_x may be made of different deformable materials and have different shapes (e.g., different sizes and/or different geometries) such that a first part of the shock absorber 65_x is stiffer than a second part of the shock absorber 65_x. For instance, in this

case, the inner part 67 of the shock absorber 65_x may be larger (e.g., have a greater diameter) than the outer part 66 of the shock absorber 65_x and may be made of the deformable material 77 which is stiffer (e.g., denser) than the deformable material 75 of the outer part 66 such that the outer part 66 deforms more than the inner part 67. In other cases, this may be reversed, with the inner part 67 of the shock absorber 65_x being smaller (e.g., have a smaller diameter) than the outer part 66 of the shock absorber 65_x and made of the deformable material 77 which is less stiff than the deformable material 75 of the outer part 66.

In embodiments such as those considered above in which different parts (e.g., the inner part 67 and the outer part 66) of the shock absorber 65_x may be configured to exhibit different levels of stiffness such that a first part (e.g., the inner part 67) of the shock absorber 65_x is stiffer than a second part (e.g. the outer part 66) of the shock absorber 65_x, the different levels of stiffness exhibited by the different parts of the shock absorber 65_x may differ in any suitable way. For example, in some embodiments, in response to an impact, a ratio of a deflection of the second part (e.g. the outer part 66) of the shock absorber 65_x in a direction of the impact over a deflection of the first part (e.g., the inner part 67) of the shock absorber 65_x in the direction of the impact may be at least 1.1, in some cases at least 1.2, in some cases at least 1.5, in some cases at least 2, and in some cases even more.

In examples in which the different parts (e.g., the inner part 67 and the outer part 66) of the shock absorber 65_x are respectively made of the deformable material 75 and the deformable material 77 which is stiffer than the deformable material 75, the deformable materials 75, 77 may differ in stiffness in any suitable way. For instance, in some embodiments, a ratio of the elastic modulus of the deformable material 77 over the elastic modulus of the deformable material 75 may be at least 1.1, in some cases at least 1.15, in some cases at least 1.2, in some cases at least 1.5, in some cases at least 2, in some cases at least 3, and in some cases even more. This ratio may have any other suitable value in other embodiments. Alternatively or additionally, in some embodiments, a ratio of a compression deflection (i.e., 25% compression deflection) of the deformable material 77 over a compression deflection of the deformable material 75 may be at least 1.1, in some cases at least 1.15, in some cases at least 1.2, in some cases at least 1.5, in some cases at least 2, in some cases at least 3, and in some cases even more, according to ASTM D-1056. This ratio may have any other suitable value in other embodiments.

In embodiments such as those considered above in which different parts (e.g., the inner part 67 and the outer part 66) of the shock absorber 65_x may be configured to exhibit different levels of stiffness such that a first part (e.g., the inner part 67) of the shock absorber 65_x is stiffer than a second part (e.g. the outer part 66) of the shock absorber 65_x, the different parts of the shock absorber 65_x may be interconnected in any suitable way. For example, in some embodiments, the different parts of the shock absorber 65_x may be adhesively bonded together. In other embodiments, the different parts of the shock absorber 65_x may be overmolded. In yet other embodiments, the different parts of the shock absorber 65_x may be fastened together by a mechanical fastener (e.g., a rivet, staple, etc.). In yet other embodiments, the different parts of the shock absorber 65_x may be welded (e.g., by ultrasonic welding). In yet other embodiments, the different parts of the shock absorber 65_x may be secured to an intermediate material disposed between them (e.g., by adhesive bonding, one or more mechanical fastener, welding, etc.).

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By way of another example, in some embodiments, as shown in Figures 68 and 69, different ones of the shock absorbers 65₁-65_N may have different shapes (e.g., different sizes and/or different geometries) and/or be made of different materials (e.g., having different densities and/or different moduli of elasticity) such that a shock absorber 65_x may be stiffer and/or otherwise react differently to an impact than another shock absorber 65_y.

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For example, in some embodiments, a shape of the shock absorber 65_x may be different than the shape of the shock absorber 65_y. In this case, a height of the shock absorber 65_x is greater than the height of the shock absorber 65_y. For instance, in some embodiments, the heights of the shock absorbers 65_x, 65_y may be such that an inner end of the shock absorber 65_x is disposed more inwardly (i.e., closer to the wearer's head 11, possibly touching it) than an inner end of the shock absorber 65_y. Also, in some embodiments, a cross-sectional dimension (e.g., a width) of the shock absorber 65_x may be greater than a cross-sectional dimension of the shock absorber 65_y.

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As another example, additionally or alternatively, in some embodiments, the deformable material 75 of the shock absorber 65_x may be different from (e.g., stiffer than) the deformable material 75 of the shock absorber 65_y. The deformable material 75 of the shock absorber 65_x

and the deformable material 75 of the shock absorber 65_y may differ in stiffness in any suitable way. For instance, in some embodiments, a ratio of a compression deflection (i.e., 25% compression deflection) of the deformable material 75 of the shock absorber 65_x over a compression deflection of the deformable material 75 of the shock absorber 65_y may be at
5 least 1.1, in some cases at least 1.15, in some cases at least 1.2, in some cases at least 1.5, and in some cases at least 2, according to ASTM D-1056. This ratio may have any other suitable value in other embodiments.

In embodiments such as those considered above in which different ones of the shock
10 absorbers 65₁-65_N may have different shapes (e.g., different sizes and/or different geometries) and/or be made of different materials to exhibit different levels of stiffness, the different levels of stiffness exhibited by the different ones of the shock absorbers 65₁-65_N may differ in any suitable way. For example, in some embodiments, in response to an impact, a ratio of a deflection of the shock absorber 65_x in a direction of the impact over a deflection of the shock
15 absorber 65_y in the direction of the impact may be at least 1.1, in some cases at least 1.2, in some cases at least 1.5, in some cases at least 2, and in some cases even more. This ratio may have any other suitable value in other embodiments.

In some embodiments, as shown in Figures 68 and 69, the different ones of the shock
20 absorbers 65₁-65_N having different shapes (e.g., different sizes and/or different geometries) and/or made of different materials may be spaced apart from one another and disposed adjacent to one another in the longitudinal direction and/or in the transversal direction of the helmet 10. In other embodiments, as shown in Figures 70 and 71, the different ones of the shock absorbers 65₁-65_N having different shapes (e.g., different sizes and/or different
25 geometries) and/or made of different materials may be disposed within one another (e.g., concentrically).

As yet other examples, although the shock absorbers 65₁-65_N are illustrated as circular in Figures 22 and 24 to 27, the shock absorbers 65₁-65_N could be pentagonal, hexagonal,
30 heptagonal, octagonal, square, rectangular, or otherwise polygonal or have any other suitable shape in other embodiments. Also, in some embodiments, a cross-sectional shape of a shock absorber 65_x may vary in a height direction of the shock absorber 65_x. For instance, as shown in Figure 72, in some embodiments, an outer part 66 of the shock absorber 65_x may taper

outwardly (i.e., towards the outer shell 12) while an inner part 67 of the shock absorber 65_x may taper inwardly (i.e., towards the wearer's head). Furthermore, while in Figures 22 and 24 to 27 the shock absorbers 65₁-65_N are of the same size and there is even spacing between them, in other embodiments, different sizing and/or different spacing of the shock absorbers
 5 65₁-65_N are possible.

As yet another example, in some embodiments, with additional reference to Figures 78 to 80, the shock-absorbing structure 32 of the inner padding 15 may comprise a shearing layer 514 disposed between an outer part 512₁ of a shock absorber 65_x and an inner part 512₂ of the
 10 shock absorber 65_x to allow the outer and inner parts 512₁, 512₂ of the shock absorber 65_x to shear relative to one another when the helmet 10 is impacted. For example, in response to a rotational impact on the helmet 10, the shearing layer 514 allows the outer part 512₁ of the shock absorber 65_x to be movable relative to the inner part 512₂ of the shock absorber 65_x in a direction tangential to an angular movement of the outer shell 12 due to the rotational
 15 impact.

In this embodiment, the shock absorbers 65₁-65_N are interconnected by the interconnector 68 and the shearing layer 514 is also disposed between an outer part 522₁ of the interconnector 68 and an inner part 522₂ of the interconnector 68 to allow the outer and inner parts 522₁,
 20 522₂ of the interconnector 68 to shear relative to one another when the helmet 10 is impacted. More particularly, in this embodiment, the interconnector 68 comprises the interconnecting members 70₁-70_M (e.g., web members) between the shock absorbers 65₁-65_N such that the shearing layer 514 is disposed between an outer part 532₁ of each interconnecting member 70_x and an inner part 532₂ of the interconnecting member 70_x to allow the outer and inner
 25 parts 532₁, 532₂ of the interconnecting member 70_x to shear relative to one another when the helmet 10 is impacted. Thus, in this case, the outer and inner parts 532₁, 532₂ of the interconnecting members 70₁-70_M respectively constitute the outer and inner parts 522₁, 522₂ of the interconnector 68.

30 The shearing layer 514 may be implemented in any suitable way in various embodiments.

In some embodiments, as shown in Figure 81, the shearing layer 514 may comprise a deformable material 540 disposed between the outer and inner parts 512₁, 512₂ of a shock

absorber 65_x and/or between the outer and inner parts 532₁, 532₂ of an interconnecting member 70_x. The deformable material 540 interconnects the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and allows them to shear relative to one another, and/or interconnects the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x and
5 allows them to shear relative to one another. In that sense, the deformable material 540 may also sometimes be referred to as a “flexible”, “elastic”, “compliant” or “resilient” material.

The deformable material 540 of the shearing layer 514 may be less rigid than a material 545 of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or less rigid than a
10 material 547 of the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x.

For example, in some embodiments, an elastic modulus of the deformable material 540 of the shearing layer 514 may be lower than an elastic modulus of the material 545 of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or lower than an elastic modulus of the
15 material 547 of the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x. In some examples, a ratio of the elastic modulus of the deformable material 540 of the shearing layer 514 over the elastic modulus of the material 545 of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or a ratio of the elastic modulus of the deformable material 540 of the shearing layer 514 over the elastic modulus of the material 547 of the outer and inner
20 parts 532₁, 532₂ of the interconnecting member 70_x may be no more than 0.9, in some cases no more than 0.7, in some cases no more than 0.5, in some cases no more than 0.3, and in some cases even less (e.g., no more than 0.1). For instance, in some embodiments, the elastic modulus of the deformable material 540 of the shearing layer may be no more than 75 MPa, in some cases no more than 65 MPa, in some cases no more than 55 MPa, in some cases less
25 than 45 MPa, and in some cases even less. The elastic modulus of the deformable material 540 of the shearing layer 540 may have any other suitable value in other embodiments.

As another example, in some embodiments, a resilience of the deformable material 540 of the shearing layer 514 may be lower than a resilience of the material 545 of the outer and inner
30 parts 512₁, 512₂ of the shock absorber 65_x and/or lower than a resilience of the material 547 of the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x. In some examples, a ratio of the resilience of the deformable material 540 of the shearing layer 514 over the resilience of the material 545 of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x

and/or a ratio of the resilience of the deformable material 540 of the shearing layer 514 over the resilience of the material 547 of the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x may be no more than 0.9, in some cases no more than 0.7, in some cases no more than 0.5, in some cases no more than 0.3, and in some cases even less (e.g., no more than 0.1). In other embodiments, this may be reversed, with the resilience of the deformable material 540 of the shearing layer 514 being greater than the resilience of the material 545 of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or greater than the resilience of the material 547 of the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x. For instance, in some embodiments, the resilience of the deformable material 540 may be at least 10%, in some cases at least 20%, in some cases at least 30%, and in some cases at least 40% according to DIN 53512 of the German institute for standardization and/or may be no more than 40%, in some cases no more than 30%, in some cases no more than 20%, and in some cases no more than 10% according to DIN 53512. The resilience of the deformable material 540 may have any other suitable value in other embodiments.

As another example, in some embodiments, a compression deflection (i.e., 25% compression deflection) of the deformable material 540 of the shearing layer 514 may be lower than a compression deflection of the material 545 of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or lower than a compression deflection of the material 547 of the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x. In some examples, a ratio of the compression deflection of the deformable material 540 of the shearing layer 514 over the compression deflection of the material 545 of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or a ratio of the compression deflection of the deformable material 540 of the shearing layer 514 over the compression deflection of the material 547 of the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x may be no more than 0.9, in some cases no more than 0.7, in some cases no more than 0.5, in some cases no more than 0.3, and in some cases even less (e.g., no more than 0.1). In other embodiments, this may be reversed, with the compression deflection of the deformable material 540 of the shearing layer 514 being lower than the compression deflection of the material 545 of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or lower than the compression deflection of the material 547 of the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x. For instance, in some embodiments, the compression deflection (i.e., 25% compression

deflection) of the deformable material 540 may be at least 5 psi, in some cases at least 10 psi, in some cases at least 20 psi, and in some cases at least 30 psi according to ASTM D-1056 and/or may be no more than 30 psi, in some cases no more than 20 psi, in some cases no more than 10 psi, and in some cases no more than 5 psi according to ASTM D-1056. The
5 compression deflection of the deformable material 540 may have any other suitable value in other embodiments.

The deformable material 540 of the shearing layer 514 may be implemented in any suitable way. For instance, in some embodiments, the deformable material 540 may comprise an
10 elastomeric material (e.g., a rubber such as styrene-butadiene rubber or any other suitable rubber; a polyurethane elastomer such as thermoplastic polyurethane (TPU); any other thermoplastic elastomer; etc.). In other embodiments, the deformable material 540 may comprise polymeric cellular material. For example, the polymeric cellular material may comprise polymeric foam such as expanded polypropylene (EPP) foam, expanded
15 polyethylene (EPE) foam, vinyl nitrile (VN) foam, polyurethane foam (e.g., PORON XRD foam commercialized by Rogers Corporation), or any other suitable polymeric foam material and/or may comprise expanded polymeric microspheres (e.g., Expancel™ microspheres commercialized by Akzo Nobel). In yet other embodiments, the deformable material 540 may comprise a fluid (e.g., a liquid or a gas), which may be contained within a container
20 (e.g., a flexible bag, pouch or other envelope) or implemented as a gel (e.g., a polyurethane gel). In yet other embodiments, the deformable material 540 may comprise a flexible plastic (e.g., low-density polyethylene).

The deformable material 540 of the shearing layer 514 can be affixed to the outer and inner
25 parts 512₁, 512₂ of the shock absorber 65_x and/or to the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x in any suitable way. For example, in some embodiments, the deformable material 540 may be affixed to the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or to the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x by adhesive bonding. For instance, in some cases, the deformable material 540 may
30 constitute an adhesive that is bonded to the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or to the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x and that can deform to allow the outer and inner parts 512₁, 512₂ of the shock absorber 65_x to shear relative to one another and/or to allow the outer and inner parts 532₁, 532₂ of the

interconnecting member 70_x to shear relative to one another. For example, in some embodiments, the deformable material 514 may be a hot-melt adhesive (e.g., a polyurethane adhesive, an ethylene-vinyl acetate (EVA) adhesive, etc.) or any other suitable adhesive. In other cases, the deformable material 540 may be bonded to the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or to the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x by an adhesive, such as a hot-melt adhesive (e.g., a polyurethane adhesive, an ethylene-vinyl acetate (EVA) adhesive, etc.) or any other suitable adhesive, disposed between the deformable material 540 and the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or between the deformable material 540 and the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x. In some embodiments, the deformable material 540 may be affixed to the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or to the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x in any other suitable manner (e.g., by chemical bonding or by one or more mechanical fasteners).

Instead of or in addition to comprising the deformable material 540, in some embodiments, as shown in Figures 82 and 83, the shearing layer 514 may comprise a void 550 between the outer and inner parts 512₁, 512₂ of a shock absorber 65_x and/or between the outer and inner parts 532₁, 532₂ of an interconnecting member 70_x. The void 550, by virtue of its absence of material, facilitates shearing of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x relative to one another and/or shearing of the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x relative to one another.

In some embodiments, as shown in Figure 82, the void 550 of the shearing layer 514 may comprise a gap 552 separating the outer and inner parts 512₁, 512₂ of the shock absorber 65_x from one another and/or separating the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x from one another. The outer and inner parts 512₁, 512₂ of the shock absorber 65_x remain linked to and aligned with one another by being connected to a remainder of the helmet 10 (e.g., to the interconnector 68 interconnecting the shock absorbers 65₁-65_N, the outer shell 12, etc.). Similarly, the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x remain linked to and aligned with one another by being connected to the remainder of the helmet 10 (e.g., to the arrangement of shock absorbers 65₁-65_N, the outer shell 12, etc.).

In other embodiments, as shown in Figure 83, the void 550 of the shearing layer 514 may comprise one or more openings 555 between the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or between the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x.

As another alternative, instead of or in addition to comprising the deformable material 540 and/or the void 550, in some embodiments, as shown in Figure 84, the shearing layer 514 may comprise a low-friction interface 560 between the outer and inner parts 512₁, 512₂ of a shock absorber 65_x and/or between the outer and inner parts 532₁, 532₂ of an interconnecting member 70_x.

The low-friction interface 560 of the shearing layer 514 is such that a coefficient of friction μ_{is} between the outer and inner parts 512₁, 512₂ of the shock absorber 65_x is lower than a coefficient of friction μ_{ms} between the material 545 of the outer part 512₁ of the shock absorber 65_x and the material 545 of the inner part 512₂ of the shock absorber 65_x, and/or a coefficient of friction μ_{ic} between the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x is lower than a coefficient of friction μ_{mc} between the material 547 of the outer part 532₁ of the interconnecting member 70_x and the material 547 of the inner part 532₂ of the interconnecting member 70_x. For example, in some embodiments, a ratio μ_{is}/μ_{ms} of the coefficient of friction μ_{is} of the low-friction interface 560 over the coefficient of friction μ_{ms} between the material 545 of the outer part 512₁ of the shock absorber 65_x and the material 545 of the inner part 512₂ of the shock absorber 65_x may be no more than 0.9, in some cases no more than 0.7, in some cases no more than 0.5, in some cases no more than 0.3, in some cases no more than 0.2, in some cases no more than 0.1, and in some cases even less, and/or a ratio μ_{ic}/μ_{mc} of the coefficient of friction μ_{ic} of the low-friction interface 560 over the coefficient of friction μ_{mc} between the material 547 of the outer part 532₁ of the interconnecting member 70_x and the material 547 of the inner part 532₂ of the interconnecting member 70_x may be no more than 0.9, in some cases no more than 0.7, in some cases no more than 0.5, in some cases no more than 0.3, in some cases no more than 0.2, in some cases no more than 0.1, and in some cases even less

For instance, in this embodiment, the low-friction interface 560 of the shearing layer 514 may comprise a low-friction element 566₁ affixed to the outer part 512₁ of the shock absorber 65_x and a low-friction element 566₂ affixed to the inner part 512₂ of the shock absorber 65_x such that the low-friction elements 566₁, 566₂ are slidable against one another when the outer and inner part 512₁, 512₂ of the shock absorber 65_x shear relative to one another, and/or a low-friction element 568₁ affixed to the outer part 532₁ of the interconnecting member 70_x and a low-friction element 568₂ affixed to the inner part 532₂ of the interconnecting member 70_x such that the low-friction elements 568₁, 568₂ are slidable against one another when the outer and inner part 532₁, 532₂ of the interconnecting member 70_x shear relative to one another.

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The low-friction elements 566₁, 566₂, 568₁, 568₂ of the low-friction interface 560 of the shearing layer 514 can be affixed to the material 545 of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or to the material 547 of the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x in any suitable way. For example, in some embodiments, the low-friction elements 566₁, 566₂, 568₁, 568₂ may be affixed to the material 545 of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or to the material 547 of the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x by adhesive bonding. In some embodiments, the low-friction elements 566₁, 566₂, 568₁, 568₂ may be affixed to the material 545 of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x and/or to the material 547 of the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x in any other suitable manner (e.g., by chemical bonding or by one or more mechanical fasteners).

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Each of the low-friction elements 566₁, 566₂, 568₁, 568₂ of the low-friction interface 560 of the shearing layer 514 comprises a low-friction material 572. For example, in some embodiments, a coefficient of friction μ_r of the low-friction material 572 according to ASTM G115 - 10 (Standard Guide for Measuring and Reporting Friction Coefficients) may be no more than 0.5, in some cases no more than 0.4, in some cases no more than 0.3, in some cases no more than 0.2, in some cases no more than 0.15, in some cases no more than 0.1.

The coefficient of friction μ_r of the low-friction material 572 may have any other suitable value in other embodiments.

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The low-friction material 572 of each of the low-friction elements 566₁, 566₂, 568₁, 568₂ of the low-friction interface 560 of the shearing layer 514 may be implemented in any suitable way. For example, in some embodiments, the low-friction material 572 may include a fluorocarbon (e.g., polytetrafluoroethylene (PTFE), such as Teflon), polyethylene, nylon, a
 5 dry lubricant (e.g., graphite, molybdenum disulfide, etc.), or any other suitable substance with a low coefficient of friction.

With the low-friction interface 560 of the shearing layer 514, the outer and inner parts 512₁, 512₂ of the shock absorber 65_x remain linked to and aligned with one another by being
 10 connected to the remainder of the helmet 10 (e.g., to the interconnector 68 interconnecting the shock absorbers 65₁-65_N, the outer shell 12, etc.), and/or the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x remain linked to and aligned with one another by being connected to the remainder of the helmet 10 (e.g., to the arrangement of shock absorbers 65₁-65_N, the outer shell 12, etc.).

15 As another possibility, in some embodiments, instead of having a low-friction interface such as the low-friction interface 560, the shearing layer 514 may comprise a high-friction interface such that the coefficient of friction μ_{is} between the outer and inner parts 512₁, 512₂ of the shock absorber 65_x is greater than the coefficient of friction μ_{ms} between the material
 20 545 of the outer part 512₁ of the shock absorber 65_x and the material 545 of the inner part 512₂ of the shock absorber 65_x, and/or the coefficient of friction μ_{ic} between the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x is greater than the coefficient of friction μ_{mc} between the material 547 of the outer part 532₁ of the interconnecting member 70_x and the material 547 of the inner part 532₂ of the interconnecting member 70_x. In some
 25 cases, this increased friction may help to dissipate energy as the outer and inner parts 512₁, 512₂ of the shock absorber 65_x shear relative to one another and/or the outer and inner parts 532₁, 532₂ of the interconnecting member 70_x shear relative to one another.

A thickness T of the shearing layer 514 may have any suitable value. For example, in some
 30 embodiments, the thickness T of the shearing layer 514 may be no more than 10 mm, in some cases no more than 5 mm, in some cases no more than 2 mm, in some cases no more than 1 mm, in some cases no more than 0.5 mm, and in some cases even less (e.g., no more than 0.2

mm). The thickness T of the shearing layer 514 may have any other suitable value in other embodiments.

The shearing layer 514 may be implemented in any other suitable way in other embodiments.

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In addition to the shearing layer 514 to facilitate shearing of the outer and inner parts 512₁, 512₂ of the shock absorbers 65₁-65_N and/or the outer and inner parts 522₁, 522₂ of the interconnector 68, in this embodiment, the material 545 of the outer part 512₁ of a shock absorber 65_x may be different from (e.g., stiffer or less stiff than; denser or less dense than; etc.) the material 545 of the inner part 512₂ of the shock absorber 65_x and/or the material 547 of the outer part 532₁ of an interconnecting member 70_x may be different from (e.g., stiffer or less stiff than; denser or less dense than; etc.) the material 547 of the inner part 532₂ of the interconnecting member 70_x. This may help to manage both high- and low-energy impacts on the helmet 10.

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For example, in some embodiments, the material 545 of the outer part 512₁ of the shock absorber 65_x may be less stiff (i.e., more flexible) than the material 545 of the inner part 512₂ of the shock absorber 65_x and/or the material 547 of the outer part 532₁ of the interconnecting member 70_x may be less stiff than the material 547 of the inner part 532₂ of the interconnecting member 70_x such that the outer part 512₁ of the shock absorber 65_x and/or the outer part 532₁ of the interconnecting member 70_x deforms more than the inner part 512₂ of the shock absorber 65_x and/or the outer part 532₂ of the interconnecting member 70_x. For instance, in some embodiments, a ratio of the elastic modulus of the material 545 of the outer part 512₁ of the shock absorber 65_x over the elastic modulus of the material 545 of the inner part 512₂ of the shock absorber 65_x may be no more than 0.9, in some cases no more than 0.8, in some cases no more than 0.7, in some cases no more than 0.6, in some cases no more than 0.5, and in some cases even less (e.g., no more than 0.3), and/or a ratio of the elastic modulus of the material 547 of the outer part 532₁ of the interconnecting member 70_x over the elastic modulus of the material 547 of the inner part 532₂ of the interconnecting member 70_x may be no more than 0.9, in some cases no more than 0.8, in some cases no more than 0.7, in some cases no more than 0.6, in some cases no more than 0.5, and in some cases even less (e.g., no more than 0.3). In other cases, this may be reversed, with the material 545 of the outer part 512₁ of the shock absorber 65_x being stiffer than the material 545 of the inner part 512₂ of the

shock absorber 65_x and/or the material 547 of the outer part 532₁ of the interconnecting member 70_x being stiffer than the material 547 of the inner part 532₂ of the interconnecting member 70_x.

5 As another example, in some embodiments, the material 545 of the outer part 512₁ of the shock absorber 65_x may be less dense than the material 545 of the inner part 512₂ of the shock absorber 65_x and/or the material 547 of the outer part 532₁ of the interconnecting member 70_x may be less dense than the material 547 of the inner part 532₂ of the interconnecting member 70_x. For instance, in some embodiments, a ratio of a density of the
10 material 545 of the outer part 512₁ of the shock absorber 65_x over a density of the material 545 of the inner part 512₂ of the shock absorber 65_x may be no more than 0.9, in some cases no more than 0.8, in some cases no more than 0.7, in some cases no more than 0.6, in some cases no more than 0.5, and in some cases even less (e.g., no more than 0.3), and/or a ratio of a density of the material 547 of the outer part 532₁ of the interconnecting member 70_x over a
15 density of the material 547 of the inner part 532₂ of the interconnecting member 70_x may be no more than 0.9, in some cases no more than 0.8, in some cases no more than 0.7, in some cases no more than 0.6, in some cases no more than 0.5, and in some cases even less (e.g., no more than 0.3). In other cases, this may be reversed, with the material 545 of the outer part 512₁ of the shock absorber 65_x being denser than the material 545 of the inner part 512₂ of the shock absorber 65_x and/or the material 547 of the outer part 532₁ of the interconnecting member 70_x being denser than the material 547 of the inner part 532₂ of the interconnecting member 70_x.
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As another example, in some embodiments, the material 545 of the outer part 512₁ of the
25 shock absorber 65_x may be less resilient than the material 545 of the inner part 512₂ of the shock absorber 65_x and/or the material 547 of the outer part 532₁ of the interconnecting member 70_x may be less resilient than the material 547 of the inner part 532₂ of the interconnecting member 70_x. For instance, in some embodiments, a ratio of the resilience of the material 545 of the outer part 512₁ of the shock absorber 65_x over the resilience of the
30 material 545 of the inner part 512₂ of the shock absorber 65_x may be no more than 0.9, in some cases no more than 0.8, in some cases no more than 0.7, in some cases no more than 0.6, in some cases no more than 0.5, and in some cases even less (e.g., no more than 0.3), and/or a ratio of the resilience of the material 547 of the outer part 532₁ of the interconnecting

member 70_x over the resilience of the material 547 of the inner part 532₂ of the interconnecting member 70_x may be no more than 0.9, in some cases no more than 0.8, in some cases no more than 0.7, in some cases no more than 0.6, in some cases no more than 0.5, and in some cases even less (e.g., no more than 0.3), according to DIN 53512 of the German institute for standardization. In other cases, this may be reversed, with the material 545 of the outer part 512₁ of the shock absorber 65_x being more resilient than the material 545 of the inner part 512₂ of the shock absorber 65_x and/or the material 547 of the outer part 532₁ of the interconnecting member 70_x being more resilient than the material 547 of the inner part 532₂ of the interconnecting member 70_x.

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As another example, in some embodiments, a compression deflection (i.e., 25% compression deflection) of the material 545 of the outer part 512₁ of the shock absorber 65_x may be less than a compression deflection of the material 545 of the inner part 512₂ of the shock absorber 65_x and/or a compression deflection of the material 547 of the outer part 532₁ of the interconnecting member 70_x may be less than a compression deflection of the material 547 of the inner part 532₂ of the interconnecting member 70_x. For instance, in some embodiments, a ratio of the compression deflection of the material 545 of the outer part 512₁ of the shock absorber 65_x over the compression deflection of the material 545 of the inner part 512₂ of the shock absorber 65_x may be no more than 0.9, in some cases no more than 0.8, in some cases no more than 0.7, in some cases no more than 0.6, in some cases no more than 0.5, and in some cases even less (e.g., no more than 0.3), and/or a ratio of the compression deflection of the material 547 of the outer part 532₁ of the interconnecting member 70_x over the compression deflection of the material 547 of the inner part 532₂ of the interconnecting member 70_x may be no more than 0.9, in some cases no more than 0.8, in some cases no more than 0.7, in some cases no more than 0.6, in some cases no more than 0.5, and in some cases even less (e.g., no more than 0.3), according to ASTM D-1056. In other cases, this may be reversed, with the compression deflection of the material 545 of the outer part 512₁ of the shock absorber 65_x being greater than that of the material 545 of the inner part 512₂ of the shock absorber 65_x and/or the compression deflection of the material 547 of the outer part 532₁ of the interconnecting member 70_x being greater than that of the material 547 of the inner part 532₂ of the interconnecting member 70_x.

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The outer and inner parts 512₁, 512₂ of the shock absorbers 65₁-65_N and the outer and inner parts 522₁, 522₂ of the interconnector 68 may be shaped in any suitable way.

For example, in this embodiment, a shock absorber 65_x includes a wall 586 defining an opening 588 such that it is tubular. Also, in this embodiment, a cross-sectional shape of the shock absorber 65_x varies in the height direction of the shock absorber 65_x. For instance, in this example, the outer part 512₁ of the shock absorber 65_x tapers outwardly (i.e., towards the outer shell 12) while the inner part 512₂ of the shock absorber 65_x tapers inwardly (i.e., towards the wearer's head 11). The opening 588 tapers inwardly in the outer part 512₁ of the shock absorber 65_x and tapers outwardly in the inner part 512₂ of the shock absorber 65_x. In this case, the cross-sectional shape of each of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x is generally circular such that each of the outer and inner parts 512₁, 512₂ of the shock absorber 65_x is generally frustoconical. The outer and inner parts 512₁, 512₂ of the shock absorber 65_x may have any other suitable shape in other embodiments (e.g., a cross-section that is pentagonal, hexagonal, heptagonal, octagonal, square, rectangular, or otherwise polygonal and/or that is constant and not tapering in the its height direction).

The outer and inner parts 512₁, 512₂ of the shock absorbers 65₁-65_N and the outer and inner parts 522₁, 522₂ of the interconnector 68 may be manufactured in any suitable way.

For example, in some embodiments, the outer parts 512₁ of the shock absorbers 65₁-65_N and the outer parts 522₁ of the interconnector 68 may be molded together as a unit constituting an outer substructure 580₁ of the shock-absorbing structure 32 and the inner parts 512₂ of the shock absorbers 65₁-65_N and the inner parts 522₂ of the interconnector 68 may be molded together as a unit constituting an inner substructure 580₂ of the shock-absorbing structure 32. Each of the outer and inner substructures 580₁, 580₂ of the shock-absorbing structure 32 may be molded using any suitable molding process. For instance, in some embodiments, each of the outer and inner substructures 580₁, 580₂ of the shock-absorbing structure 32 may be molded using an injection molding process, a foam-expansion molding process, a compression molding process, etc.

Upon being molded, the outer and inner substructures 580₁, 580₂ of the shock-absorbing structure 32 may be secured together such as to create the shearing layer 514 between them.

As an example, in some embodiments, the deformable material 540 of the shearing layer 514 may be affixed to the outer and inner substructures 580₁, 580₂ of the shock-absorbing structure 32 in between them in order to secure them to one another. As another example, in some embodiments, the outer and inner substructures 580₁, 580₂ of the shock-absorbing structure 32 may be linked to and aligned with one another by being connected to the remainder of the helmet 10 (e.g., the outer shell 12, another component of the inner padding 15, etc.).

1.2 *Arrangement of shock absorbers connected to at least one other helmet component by connectors which are deformable in response to a rotational impact*

In some embodiments, as shown in Figures 35 and 36, the inner padding 15 may comprise an arrangement (e.g., an array) of shock absorbers 165₁-165_N that is connected to one or more other helmet components (e.g., the outer shell 12 and/or another layer of the inner padding 15) by a plurality of connectors 85₁-85_C which are deformable in response to a rotational impact on the helmet 10 such that the arrangement of shock absorbers 165₁-165_N moves relative to the outer shell 12 in a direction tangential to an angular movement of the outer shell 12 due to the rotational impact. This elastic deformation of the connectors 85₁-85_C absorbs energy from the rotational impact and may thus reduce its effect on the wearer's head 11.

The shock absorbers 165₁-165_N may be configured like the shock absorbers 65₁-65_N discussed above in section 1.1. Also, the inner padding 15 may comprise an interconnector 168 interconnecting the shock absorbers 165₁-165_N. The interconnector 168 may be configured like the interconnector 68 discussed above in section 1.1.

In this embodiment, the connectors 85₁-85_C connect the arrangement of shock absorbers 165₁-165_N to the outer shell 12. More particularly, in this embodiment, each connector 85_x comprises a fastener 86 fastening it to the arrangement of shock absorbers 165₁-165_N and a fastener 87 fastening it to the outer shell 12. Specifically, in this embodiment, the fastener 86 fastens the connector 85_x to a shock absorber 165_y and the fastener 87 fastens the connector 85_x to the outer shell 12. By way of example, the fastener 86 may be an adhesive fastener, a

mechanical fastener (e.g., screw or other threaded fastener, rivet, etc.) or any other suitable fastener.

The connector 85_x is deformable when the outer shell 12 angularly moves due to a rotational impact to allow the arrangement of shock absorbers 165₁-165_N to move relative to the outer shell 12 in a direction tangential to the outer shell's angular movement. For example, Figure 37 illustrates in dotted lines the connector 85_x deformed when the outer shell 12 angularly moves due to a rotational impact. For instance, in various embodiments, the connector 85_x may be stretchable, bendable, and/or shearable.

The connector 85_x comprise a deformable material 89. The deformable material 89 may also sometimes be referred to as a "flexible", "elastic", "compliant" or "resilient" material.

The deformable material 89 may have an elastic modulus (i.e., modulus of elasticity) within a certain range to provide suitable elastic deformation. For example, in some embodiments, the elastic modulus of the deformable material 89 of the connector 85_x may be different from (e.g., greater or lower than) an elastic modulus of a material 175 of the arrangement of shock absorbers 165₁-165_N. For instance, in some embodiments, the elastic modulus of the deformable material 89 of the connector 85_x may be lower than the elastic modulus of the material 175 of the arrangement of shock absorbers 165₁-165_N. In some examples, a ratio of the elastic modulus of the deformable material 89 of the connector 85_x over the elastic modulus of the material 175 of the arrangement of shock absorbers 165₁-165_N may be no more than 0.9, in some cases no more than 0.7, in some cases no more than 0.5, in some cases no more than 0.3, and in some cases even less (e.g., no more than 0.1). For instance, in some embodiments, the elastic modulus of the deformable material 89 of the connector 85_x may be no more than 75 MPa, in some cases no more than 65 MPa, in some cases no more than 55 MPa, and in some cases even less. The elastic modulus of the deformable material 89 of the connector 85_x may have any other suitable value in other embodiments.

For example, in some embodiments, the deformable material 89 may comprise an elastomeric material (e.g., a rubber such as styrene-butadiene rubber or any other suitable rubber; a polyurethane elastomer such as thermoplastic polyurethane (TPU); any other thermoplastic elastomer; etc.). Alternatively, in other embodiments, the deformable material 89 may

comprise polymeric cellular material. For instance, the polymeric cellular material may comprise polymeric foam such as expanded polypropylene (EPP) foam, expanded polyethylene (EPE) foam, vinyl nitrile (VN) foam, polyurethane foam (e.g., PORON XRD foam commercialized by Rogers Corporation), or any other suitable polymeric foam material and/or may comprise expanded polymeric microspheres (e.g., Expancel™ microspheres commercialized by Akzo Nobel). In yet other embodiments, the deformable material 89 may comprise a fluid (e.g., a liquid or a gas), which may be contained within a container (e.g., a flexible bag, pouch or other envelope) or implemented as a gel (e.g., a polyurethane gel). As yet another example, in other embodiments, the deformable material 89 may comprise a flexible plastic (e.g., low-density polyethylene).

The connectors 85₁-85_C may be configured in various other ways in other embodiments.

For example, in other embodiments, as shown in Figure 38, a fastener 86 of a connector 85_x may fasten the connector 85_x to the interconnector 168 as opposed to any of the shock absorbers 165₁-165_N. In this example, the outer parts 166 of the shock absorbers 165₁-165_N, in the absence of an impact on the helmet 10, are not connected, interfaced or otherwise engaged with any component of the helmet (e.g., the outer shell 12). In other examples, the outer parts 166 of the shock absorbers 165₁-165_N may be connected, interfaced, or otherwise engaged with another component of the helmet (e.g., such as the frictional interface 80 with the outer shell 12 discussed above in section 1.1).

By way of another example, in other embodiments, as shown in Figure 39, the connectors 85₁-85_C may connect the arrangement of shock absorbers 165₁-165_N to another layer 88 of the inner padding 15. For instance, in some embodiments, a fastener 87 of a connector 85_x may be fastened to the layer 88 of the inner padding 15 to the shell 12.

As illustrated in Figures 35 and 39, in some embodiments, some of the shock absorbers 165₁-165_N may not be connected with the connectors 85₁-85_C. Any suitable selection of which shock absorbers 165₁-165_N connect with the connectors 85₁-85_C is possible. Alternatively, in other embodiments, all of the shock absorbers 165₁-165_N may be connected with the connectors 85₁-85_C. Furthermore, in other embodiments, multiple fasteners (i.e., two or more) may be connected to a single shock absorber 165_x.

In some embodiments, both (i) the shock absorbers 165₁-165_N and (ii) the connectors 85₁-85_C may be deformable when the outer shell 12 angularly moves due to a rotational impact. In other embodiments, only the connectors 85₁-85_C may be deformable when the outer shell 12 angularly moves due to a rotational impact, with the shock absorbers 165₁-165_N substantially keeping their shape from prior to the rotational impact.

1.3 Meshing protective layers movable relative to one another and deformable in response to a rotational impact

In some embodiments, as shown in Figure 40, the rotational impact protection system 28 may comprise a plurality of protective layers 90₁-90_P which are meshing with one another, such that a first protective layer 90_i of the protective layers 90₁-90_P meshes with a second protective layer 90_j of the protective layers 90₁-90_P. The protective layers 90_i, 90_j are “meshing” in that they are in a meshing relationship, i.e., a given one of the protective layers 90_i, 90_j extends into the other one of the protective layers 90_i, 90_j. To that end, a meshing part 91 of the given one of the protective layers 90_i, 90_j extends into a meshing hollow space 92 of the other one of the protective layers 90_i, 90_j. The meshing hollow space 92 may comprise one or more recesses, holes, and/or other hollow areas. This meshing relationship increases resistance to relative movement of the protective layers 90_i, 90_j, which in turn increases how much energy is needed to move them. More energy is required since the meshing part 91 of the given one of the protective layers 90_i, 90_j and/or the meshing hollow space 92 of the other one of the protective layers 90_i, 90_j must deform sufficiently to move the meshing part 91 out of the meshing hollow space 92.

In this embodiment, the protective layer 90_j is implemented by the inner padding 15 and comprises the meshing part 91, and the protective layer 90_i is implemented by the outer shell 12 and comprises the meshing hollow space 92. In this case, the meshing part 91 of the inner padding 15 comprises a plurality of projections 95₁-95_P and the meshing hollow space of the outer shell 12 comprises a plurality of recesses 96₁-96_P receiving corresponding ones of the projections 95₁-95_P. More specifically, in this case, each of the projections 95₁-95_P are deformable to move out of the recesses 96₁-96_P when the outer shell 12 angularly moves due to a rotational impact. For instance, in the example illustrated in Figure 41, the protective

layer 90_j is deformed and is moved relative to the protective layer 90_i in response to a rotational impact causing an angular movement of the outer shell 12.

Each projection 95_x may comprise a deformable material 97. The deformable material 97
5 may sometimes be referred to as a “flexible”, “elastic”, “compliant” or “resilient” material.

The deformable material 97 may have an elastic modulus (i.e., modulus of elasticity) within a certain range to provide suitable elastic deformation. For example, in some embodiments, the elastic modulus of the deformable material 97 of the projection 95_x may be no more than 75
10 MPa, in some cases no more than 65 MPa, in some cases no more than 55 MPa, and in some cases even less (e.g., less than 50 MPa). The elastic modulus of the deformable material 97 of the projection 95_x may have any other suitable value in other embodiments.

For example, in some embodiments, the deformable material 97 may comprise polymeric
15 cellular material. For instance, the polymeric cellular material may comprise polymeric foam such as expanded polypropylene (EPP) foam, expanded polyethylene (EPE) foam, vinyl nitrile (VN) foam, polyurethane foam (e.g., PORON XRD foam commercialized by Rogers Corporation), or any other suitable polymeric foam material and/or may comprise expanded polymeric microspheres (e.g., ExpanceTM microspheres commercialized by Akzo Nobel).
20 Alternatively, in other embodiments, the deformable material 97 may comprise an elastomeric material (e.g., a rubber such as styrene-butadiene rubber or any other suitable rubber; a polyurethane elastomer such as thermoplastic polyurethane (TPU); any other thermoplastic elastomer; etc.). In yet other embodiments, the deformable material 97 may comprise a flexible plastic such as low-density polyethylene.

25 The projections 95₁-95_p may have any suitable shape. For instance, in some embodiments, the projections 95₁-95_p may be hemispherical or polygonal, or have a periphery with both flat and curved areas.

30 In some embodiments, to allow adjustability of the helmet 10, the recesses 96₁-96_p may be sufficiently large such that they register with respective ones of the projections 95₁-95_p in a number of different positions. For example, in some embodiments, each recess 96_x may be elongated in a direction in which a pad member of the inner padding 15 having a projection

95_x registering with the recess 96_x moves when the helmet 10 is adjusted using the adjustment mechanism 40. A width of the recess 96_x transversal to its length may generally match a diameter of the projection 95_x.

- 5 The protective layers 90_i-90_p which are meshing with one another may be configured in various other ways in other embodiments.

For example, in other embodiments, as shown in Figure 42, the reverse arrangement in which the protective layer 90_j implemented by the inner padding 15 comprises recesses 196_i-196_p and the protective layer 90_i implemented by the outer shell 12 comprises projections 195_i-195_p may be used. In this case, each of the projections 195_i-195_p is not deformable and the recesses 196_i-196_p of the protective layer 90_j are deformable to move relative to the protective layer 90_i when the outer shell 12 angularly moves due to a rotational impact. Alternatively, in other cases, each of the projections 195_i-195_p may be deformable to move out of the recesses 196_i-196_p when the outer shell 12 angularly moves due to a rotational impact. For instance, the projections 195_i-195_p may be made of a different material or of a more flexible material than the rest of the shell 12.

As another example, in other embodiments, as shown in Figure 43, each of the protective layer 90_i implemented by the inner padding 15 and the protective layer 90_j implemented by the outer shell 12 may comprise both projections 295_i-295_p and recesses 296_i-296_p. As in the cases discussed above, each of the projections 295_i-295_p may be deformable to move out of the recesses 296_i-296_p when the outer shell 12 angularly moves due to a rotational impact. Alternatively, in some cases, only a selective subset of the projections 295_i-295_p may be deformable. For instance, in one example, the projections 295₁, 295₃, 295₅, ... 295_{p-1} may be deformable while the other projections 295₂, 295₄, 295₆, ... 295_p may not be deformable.

By way of another example, in some embodiments, as shown in Figure 44, the protective layer 90_i may be implemented by a first padding layer 98 of the inner padding 15 and the protective layer 90_j may be implemented by a second padding layer 99 of the inner padding 15. In this case, the padding layers 98, 99 are movable relative to one another. For instance, the padding layers 98, 99 may be individually fastened to the outer shell 12 (e.g., at different locations) by respective fasteners to allow their relative movement. Alternatively, the

padding layers 98, 99 may be directly connected to one another by a fastener (e.g., screw or other threaded fastener, rivet, etc., or any other suitable fastener) that allows them to move relatively to one another. In some embodiments, the deformable material 97 of the padding layer 98 may be stiffer or less stiff than the deformable material 97 of the padding layer 99.

- 5 Both projections 395₁-395_P and recesses 396₁-396_P of the padding layers 98, 99 may be deformable.

Although in embodiments discussed above there are only two protective layers 90_i and 90_j meshing, in other embodiments, there may be three or more protective layers 90₁-90_P that are meshing. For instance, in some embodiments, a protective layer 90_i may be implemented by a first padding layer 98 of the inner padding 15 and a protective layer 90_j may be implemented by a second padding layer 99 of the inner padding 15 as shown above in Figure 44, and a protective layer 90_k may be implemented by the outer shell 12 as shown in Figure 40.

15 *1.4 Shearable material which can elastically shear in response to a rotational impact*

In some embodiments, as shown in Figures 45 and 46, the rotational impact protection system 28 may comprise a shearable material 102 which can elastically shear in response to a rotational impact on the helmet 10 such that its outer surface 103 is movable relative to its inner surface 105 in a direction tangential to an angular movement of the outer shell 12 due to the rotational impact. This elastic shear of the shearable material 102 absorbs energy from the rotational impact and may thus reduce its effect on the wearer's head 11.

25 In this embodiment, the shearable material 102 may constitute at least part of the inner padding 15.

More particularly, in some embodiments, the shearable material 102 may have a shear modulus within a certain range to provide suitable shearability. For example, in some embodiments, the shear modulus of the shearable material 102 may be no more than 20 MPa, in some cases no more than 10 MPa, in some cases no more than 5 MPa, and in some cases even less. The shear modulus of the shearable material 102 may have any other suitable value in other embodiments.

Additionally or alternatively, in some embodiments, the shearable material 102 may have a hardness within a certain range to provide suitable shearability. For example, in some embodiments, the hardness of the shearable material 102 may be no more than 90 durometers Shore OO, in some cases no more than 70 durometers Shore OO, in some cases no more than 50 durometers Shore OO, in some cases no more than 30 durometers Shore OO, and in some cases even less (e.g., no more than 20 durometers Shore OO). The hardness of the shearable material 102 may have any other suitable value in other embodiments.

Yet additionally or alternatively, in some embodiments, the shearable material 102 may have a resilience within a certain range to provide suitable shearability. For example, in some embodiments, the resilience of the shearable material 102 may be at least 5%, in some cases at least 10%, in some cases at least 20%, and in some cases at least 30% according to DIN 53512 of the German institute for standardization and/or may be no more than 30%, in some cases no more than 20%, in some cases no more than 10%, and in some cases no more than 5% according to DIN 53512. The resilience of the shearable material 102 may have any other suitable value in other embodiments.

For example, in some embodiments, the hardness of the shearable material 102 may be between 20 and 90 durometers Shore OO and the resilience of the shearable material 102 may be no more than 30% according to DIN 53512.

A thickness T of the shearable material 102 may be with a certain range for suitable shearability. For example, in some embodiments, the thickness T of the shearable material 102 may be no more than 20 mm, in some cases no more than 10 mm, in some cases no more than 5 mm, and in some cases even less (e.g., no more than 1 mm). The thickness T of the shearable material 102 may have any other suitable value in other embodiments.

The shearable material 102 may be of any suitable type in various embodiments.

For example, in some embodiments, the shearable material 102 may comprise an elastomeric material (e.g., a rubber or a polyurethane elastomer).

As another example, in some embodiments, the shearable material 102 may comprise polymeric cellular material. For instance, the polymeric cellular material may comprise polymeric foam such as vinyl nitrile (VN) foam, expanded polypropylene (EPP) foam, expanded polyethylene (EPE) foam, polyurethane foam (e.g., PORON XRD foam
5 commercialized by Rogers Corporation), or any other suitable polymeric foam material and/or may comprise expanded polymeric microspheres (e.g., Expancel™ microspheres commercialized by Akzo Nobel).

By way of another example, in some embodiments, the shearable material 102 may comprise
10 a fluid (e.g., a liquid or a gas). In some cases, the fluid may be contained within a container (e.g., a flexible bag, pouch or other envelope). In other cases, the shearable material 102 may comprise a gel. For instance, in some embodiments, the gel may be a polyurethane gel.

In yet another example, in some embodiments, as shown in Figures 47 to 49, the shearable
15 material 102 may comprise a viscous medium 110 containing particles 112₁-112_v. This may allow the shearable material 102 to be viscoelastic. For instance, in this embodiment, the shearable material 102 may be malleable such that it is repeatedly deformable and substantially retains any of a plurality of shapes it can acquire. For example, Figure 47 shows an original shape of the shearable material 102, while Figures 48 and 49 show different
20 shapes of the shearable material 102 that it retains upon being deformation. For instance, the shape that the shearable material 102 retains may depend on the shape of the wearer's head 11 in the helmet 10, as the shearable material 102 may form to fit the wearer's head 11. For example, in some embodiments, the viscous medium 110 may be oil and the particles 112₁-112_v may be expanded polymeric microspheres (e.g., Expancel™ microspheres
25 commercialized by Akzo Nobel).

The shearable material 102 may be configured in various other ways in other embodiments.

For example, as illustrated in Figures 50 and 51, the shearable material 102 may form an
30 interface layer 109 disposed between the outer shell 12 and the inner padding 15. For instance, Figure 51 illustrates in dotted lines a shearing of the shearable material 102 in response to an angular movement of the outer shell. In this embodiment, the interface layer 109 is fastened to outer shell 12 and the inner padding 15 by fasteners, which may be an

adhesive fastener, a mechanical fastener (e.g., screw or other threaded fastener, rivet, etc.) or any other suitable fastener.

1.5 *Floating liner*

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In some embodiments, as shown in Figures 52 to 54, the rotational impact protection system 28 of the helmet 10 may comprise a floating liner 450 disposed between the outer shell 12 and the wearer's head 11 and movable relative to the inner padding 15 and the outer shell 12 in response to a rotational impact. In this example, the floating liner 450 is disposed between
10 the inner padding 15 and the wearer's head 11. In other examples, the floating liner 450 may be disposed elsewhere between the outer shell 12 and the wearer's head 11, such as, for instance, between the outer shell 12 and the inner padding 15.

For example, in some embodiments, the floating liner 450 may be configured as described in
15 U.S. Patent Application 13/560,546, which was published as U.S. Patent Application Publication 2013/0025032 on January 31, 2013. As discussed therein, in some embodiments, energy from a rotational impact is absorbed by a frictional engagement of the floating liner 450 with the inner padding 15 in which energy is dissipated through friction and by an elastic deformation of the floating liner 450 in which energy is absorbed through stretching of the
20 floating liner 450. In addition to its rotational impact protection, in some embodiments, the floating liner 450 also provides linear impact protection. More particularly, the floating liner 450 is elastically compressible in response to a linear impact force to absorb energy by elastic compression.

25 In this embodiment, the floating liner 450 comprises an inner surface 459 for contacting the wearer's head 11 and an outer surface 461 facing the inner padding 15. In this case, the inner surface 459 of the floating liner 450 constitutes the internal surface 20 of the helmet 10 which contacts the wearer's head 11 when the helmet 10 is worn.

30 Also, in this embodiment, the floating liner 450 comprises a front portion 453 for facing the front region FR of the wearer's head 11, left and right side portion 455 for facing the left and right side regions LS, RS of the wearer's head 11, a top portion 465 for facing the top region TR of the wearer's head 11, and a back portion 467 for facing the back region BR of the

wearer's head 11. These portions of the floating liner 450 are arranged such that the floating liner 450 has a dome shape for receiving the wearer's head 11. In this example, the front portion 453, side portions 455, and back portion 467 comprise respective segments 470₁-470₆ extending downwardly from the top portion 465 and spaced from one another. The floating
 5 liner 450 may have various other shapes in other embodiments.

The floating liner 450 may be made of any suitable material to achieve its impact protection function. In this embodiment, in order to absorb energy by elastic deformation, the floating liner 450 comprises elastic material that is elastically stretchable to absorb energy by
 10 stretching when the helmet 10 is rotationally impacted. Also, in this case, the elastic material of the floating liner 450 is elastically compressible to absorb energy by compressing when the helmet 10 is impacted. The elastic material of the floating liner 450 may thus be an elastically stretchable compressible impact-absorbing material. For example, in some
 15 embodiments, the elastic material of the floating liner 450 may comprise elastomeric material (e.g., elastomeric polyurethane foam such as PORON XRD foam commercialized by Rogers Corporation or any other suitable elastomeric foam).

The floating liner 450 may be configured in various other ways in other embodiments. Examples of variants of the floating liner 450 are discussed in U.S. Patent Application
 20 Publication 2013/0025032.

1.6 Compression of padding layers decoupled from shearing of the padding layers

In some embodiments, as shown in Figures 73 to 76, the rotational impact protection system
 25 of the helmet 10 may be implemented by the inner padding 15 comprising a plurality of padding layers 330₁-330_P that are stacked and interconnected such that compression of adjacent ones of the padding layers 330₁-330_P is decoupled (i.e., independent) from shearing of these adjacent ones of the padding layers 330₁-330_P relative to one another. This may
 30 allow the inner padding 15 to better absorb linear impact forces by compression of the padding layers 330₁-330_P and rotational impact forces by shearing of adjacent ones of the padding layers 330₁-330_P relative to one another. For example, in response to a rotational impact on the helmet 10, an outer one of the padding layers 330₁-330_P may be movable relative to an inner one of the padding layers 330₁-330_P in a direction tangential to an angular

movement of the outer shell 12 due to the rotational impact, potentially with little or no compression of one or both of these outer and inner ones of the padding layers 330₁-330_p.

In this embodiment, the inner padding 15 comprises a plurality of pad members 344₁-344_p separate from one another, in which each pad member 344_i comprises a plurality of padding layers 348₁-348₃ that are stacked and a connector 350 interconnecting adjacent ones of the padding layers 348₁-348₃ such that compression of the padding layers 348₁-348₃ is decoupled (i.e., independent) from shearing of the adjacent ones of the padding layers 348₁-348₃ relative to one another. Thus, in this embodiment, the padding layers 348₁-348₃ of each of the pad members 344₁-344_p constitute respective ones of the padding layers 330₁-330_p of the inner padding 15. Also, in this embodiment, the pad member 344_i comprises a low-friction interface 370 between adjacent ones of the padding layers 348₁-348₃ to facilitate shearing of these adjacent padding layers relative to one another.

In response to a rotational impact on the helmet 10, an outer one of the padding layers 348₁-348₃ of a pad member 344_i may be movable relative to an inner one of the padding layers 348₁-348₃ of the pad member 344_i in a direction tangential to an angular movement of the outer shell 12 due to the rotational impact, potentially with little or no compression of one or both of these outer and inner ones of the padding layers 348₁-348₃. In this example of implementation, because of separateness of the pad members 344₁-344_p, the outer and inner ones of the padding layers 348₁-348₃ of the pad member 344_i may move omnidirectionally relative to one another (i.e., may move relative to one another in any direction in a plane between them). This may be particularly useful in embodiments such as those considered here where the helmet 10 does not have a perfectly spherical configuration.

In this example, the padding layer 348₁ of each of the pad members 344₁-344_p is secured to the outer shell 12 (e.g., by an adhesive, one or more mechanical fasteners, etc.) in order to secure the pad members 344₁-344_p and provide anchoring points for shearing purposes. In other examples, the pad members 344₁-344_p may be secured in any other suitable way within the helmet 10.

Each of the padding layers 348₁-348₃ of a pad member 344_i comprises a shock-absorbing material 355. For example, in some embodiments, the shock-absorbing material 355 may

comprise polymeric cellular material. For instance, the polymeric cellular material may comprise polymeric foam such as expanded polypropylene (EPP) foam, expanded polyethylene (EPE) foam, vinyl nitrile (VN) foam, polyurethane foam (e.g., PORON XRD foam commercialized by Rogers Corporation), or any other suitable polymeric foam material and/or may comprise expanded polymeric microspheres (e.g., ExpancelTM microspheres commercialized by Akzo Nobel). In other embodiments, the shock-absorbing material 355 may comprise an elastomeric material (e.g., a rubber such as styrene-butadiene rubber or any other suitable rubber; a polyurethane elastomer such as thermoplastic polyurethane (TPU); any other thermoplastic elastomer; etc.). In yet other embodiments, the shock-absorbing material 355 may comprise a fluid (e.g., a liquid or a gas), which may be contained within a container (e.g., a flexible bag, pouch or other envelope) or implemented as a gel (e.g., a polyurethane gel). Any other material with suitable impact energy absorption may be used in other embodiments.

The shock-absorbing material 355 of each of the padding layers 348₁-348₃ of the pad member 344_i is compressible in response to an impact. In some examples, a compressibility of the shock-absorbing material 355 may be greater than a shearability of the shock-absorbing material 355. That is, the shock-absorbing material 355 may deform by compression more easily than by shearing.

In some cases, the shock-absorbing material 355 of a padding layer 348_x may be the same as the shock-absorbing material 355 of another padding layer 348_y.

In other cases, the shock-absorbing material 355 of a padding layer 348_x may be different than the shock-absorbing material 355 of another padding layer 348_y. For example, in some embodiments, the shock-absorbing material 355 of the padding layer 348_x may be stiffer than the shock-absorbing material 355 of the padding layer 348_y that is more inwards (i.e., closer to the wearer's head 11) than the padding layer 348_x. For instance, in some examples, the shock-absorbing material 355 of the padding layer 348₁ may be stiffer than the shock-absorbing material 355 of the padding layer 348₂ that is more inwards (i.e., closer to the wearer's head 11) than the padding layer 348₁, and/or the shock-absorbing material 355 of the padding layer 348₂ may be stiffer than the shock-absorbing material 355 of the padding

layer 348₃ that is more inwards (i.e., closer to the wearer's head 11) than the padding layer 348₂.

For example, in some embodiments, the shock-absorbing material 355 of the padding layer 348₁ and the shock-absorbing material 355 of the padding layer 348₂ may provide a bulk of a shock absorption capability of the pad member 344_i, while the shock-absorbing material 355 of the padding layer 348₃ may be primarily for comfort of the wearer (e.g., the padding layer 348₃ may be a comfort padding layer contacting the wearer's head 11 when the helmet 10 is being worn).

Each of the padding layers 348₁-348₃ of the pad member 344_i can have any suitable shape. In this embodiment, each of the padding layers 348₁-348₃ has a generally circular cross-section such that it is generally cylindrical. The padding layers 348₁-348₃ may have any other suitable shape in other examples. Also, in some examples, different ones of the padding layers 348₁-348₃ may have different shapes.

The pad member 344_i may include any number of padding layers that are stacked and interconnected such as the padding layers 348₁-348₃ in other embodiments (i.e., two or more than three padding layers such as the padding layers 348₁-348₃).

The connector 350 of the pad member 344_i interconnects adjacent ones of the padding layers 348₁-348₃ of the pad member 344_i. In this embodiment, the connector 350 connects the padding layers 348₁, 348₂ to one another. The padding layers 348₂, 348₃ may be secured to one another by an adhesive and/or a mechanical fastener and/or in any other way (e.g., ultrasonic welding, overmolding, etc.).

The connector 350 is deformable to allow the padding layers 348₁, 348₂ of the pad member 344_i to shear relative to one another. More particularly, in this embodiment, the connector 350 is stretchable and/or bendable to allow the padding layers 348₁, 348₂ of the pad member 344_i to shear relative to one another. Thus, in response to a rotational impact on the helmet 10, the connector 350 is deformable to allow the padding layers 348₁, 348₂ to move relative to one another in a direction tangential to an angular movement of the outer shell 12 due to the rotational impact.

In this embodiment, the connector 350 of the pad member 344_i comprises a plurality of connecting members 354₁-354₄ that are separate from one another. More particularly, in this embodiment, each of the connecting members 354₁-354₄ is elongated and extends from the padding layer 348₁ to the padding layer 348₂ to interconnect these padding layers. In that sense, the connecting members 354₁-354₄ may be referred to as connecting “columns”. In this example, each of the connecting members 354₁-354₄ has a generally circular cross-section such that it is generally cylindrical. The connecting members 354₁-354₄ may have any other suitable shape in other examples. Also, in some examples, different ones of the connecting members 354₁-354₄ may have different shapes.

Each connecting member 354_x of the pad member 344_i comprises a deformable material 360. The deformable material 360 may sometimes be referred to as a “flexible”, “elastic”, “compliant” or “resilient” material.

The deformable material 360 of a connecting member 354_x may have an elastic modulus (i.e., modulus of elasticity) within a certain range to provide suitable elastic deformation. For example, in some embodiments, the elastic modulus of the deformable material 360 of the connecting member 354_x may be different from (e.g., greater or lower than) an elastic modulus of the shock-absorbing material 355 of a padding layer 348_x of the pad member 344_i. For instance, in some embodiments, the elastic modulus of the deformable material 360 of the connecting member 354_x may be lower than the elastic modulus of the shock-absorbing material 355 of the padding layer 348_x. In some examples, a ratio of the elastic modulus of the deformable material 360 of the connecting member 354_x over the elastic modulus of the shock-absorbing material 355 of the padding layer 348_x may be no more than 0.9, in some cases no more than 0.7, in some cases no more than 0.5, in some cases no more than 0.3, and in some cases even less (e.g., no more than 0.1). For instance, in some embodiments, the elastic modulus of the deformable material 360 of the connecting member 354_x may be no more than 50 MPa, in some cases no more than 35 MPa, in some cases less than 20 MPa, and in some cases even less (e.g., no more than 10 MPa). The elastic modulus of the deformable material 360 of the connector 354_x may have any other suitable value in other embodiments.

For example, in some embodiments, the deformable material 360 of a connecting member 354_x of the pad member 344_i may comprise an elastomeric material (e.g., a rubber such as styrene-butadiene rubber or any other suitable rubber; a polyurethane elastomer such as thermoplastic polyurethane (TPU); any other thermoplastic elastomer; etc.). Alternatively, in
5 other embodiments, the deformable material 360 may comprise polymeric cellular material. For instance, the polymeric cellular material may comprise polymeric foam such as expanded polypropylene (EPP) foam, expanded polyethylene (EPE) foam, vinyl nitrile (VN) foam, polyurethane foam (e.g., PORON XRD foam commercialized by Rogers Corporation), or any other suitable polymeric foam material and/or may comprise expanded polymeric
10 microspheres (e.g., Expancel™ microspheres commercialized by Akzo Nobel). As yet another example, in other embodiments, the deformable material 360 may comprise a flexible plastic (e.g., low-density polyethylene).

The connector 350 of the pad member 344_i can be secured to the padding layers 348₁, 348₂ of
15 the pad member 344_i in any suitable way. In this embodiment, each connecting member 354_x comprises enlarged end portions 366₁, 366₂ that engage respective ones of the padding layers 348₁, 348₂ to secure them together. More particularly, in this embodiment, each of the padding layers 348₁, 348₂ comprises a plurality of channels 368₁-368₄ that receive respective
20 ones of the connecting members 354₁-354₄ such that the padding layers 348₁, 348₂ are disposed and retained between the enlarged end portions 366₁, 366₂ of each of the connecting members 354₁-354₄. The channels 368₁-368₄ may be formed by drilling, punching, molding, or in any other suitable way. In some examples, the connecting members 354₁-354₄ with their
25 enlarged end portions 366₁, 366₂ may be inserted through the channels 368₁-368₄ via a one-way plug. In other examples, the enlarged end portions 366₁, 366₂ of the connecting members 354₁-354₄ may be formed after insertion of the connecting members 354₁-354₄ through the channels 368₁-368₄, such as by thermoforming (e.g., heat-forming a thermoplastic-elastomer filament) and/or by any other suitable process. The connector 350 of the pad member 344_i may be secured to the padding layers 348₁, 348₂ in any other suitable manner in other
embodiments (e.g., by adhesive bonding, using one or more mechanical fasteners, etc.).

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In this embodiment, the connector 350 of the pad member 344_i allows the pad member 344_i to have a compact size. This may help to avoid increasing an offset of the helmet 10 from the wearer's head 11 (i.e., a distance between the wearer's head 11 and the external surface 18 of

the helmet 10). More particularly, in this embodiment, the connector 350 is concealed by the padding layers 348₁-348₃ of the pad member 344_i and does not affect a thickness of the pad member 344_i. That is, the thickness of the pad member 344_i would remain identical if the connector 350 was removed from the pad member 344_i but the pad member 344_i was
 5 otherwise identical. In this case, the connecting members 354₁-354₄ of the connector 350 are located in the channels 368₁-368₄ of the padding layers 348₁, 348₂, thus concealed by the padding layers 348₁, 348₂ and not adding to the thickness of the pad member 344_i.

The connector 350 of the pad member 344_i may be configured in any other suitable way in
 10 other embodiments. For instance, in other embodiments, the connector 350 of the pad member 344_i may be constituted by a single connecting member or may comprise any suitable number of connecting members such as the connecting members 354₁-354₄ (e.g., two, three, or more than four connecting members).

15 In this embodiment, the low-friction interface 370 of the pad member 344_i is disposed between the padding layers 348₁, 348₂ in order to facilitate shearing of the padding layers 348₁, 348₂ relative to one another. The low-friction interface 370 is such that a coefficient of friction μ_i between the padding layers 348₁, 348₂ is lower than a coefficient of friction μ_m between the shock-absorbing material 355 of the padding layer 348₁ and the shock-absorbing
 20 material 355 of the padding layer 348₂. For example, in some embodiments, a ratio μ_i/μ_m of the coefficient of friction μ_i of the low-friction interface 370 over the coefficient of friction μ_m between the shock-absorbing material 355 of the padding layer 348₁ and the shock-absorbing material 355 of the padding layer 348₂ may be no more than 0.9, in some cases no more than 0.7, in some cases no more than 0.5, in some cases no more than 0.3, in some
 25 cases no more than 0.2, in some cases no more than 0.1, and in some cases even less.

More particularly, in this embodiment, the low-friction interface 370 of the pad member 344_i comprises a low-friction element 372₁ affixed to the shock-absorbing material 355 of the padding layer 348₁ and a low-friction element 372₂ affixed to the shock-absorbing material
 30 355 of the padding layer 348₂ such that the low-friction elements 372₁, 372₂ are slidable against one another when the padding layers 348₁, 348₂ shear relative to one another.

The low-friction elements 372₁, 372₂ of the low-friction interface 370 of the pad member 344_i can be affixed to the shock-absorbing material 355 of the padding layers 348₁, 348₂ in any suitable way. For example, in some embodiments, the low-friction elements 372₁, 372₂ may be affixed to the shock-absorbing material 355 of the padding layers 348₁, 348₂ by
5 adhesive bonding. In some embodiments, the low-friction elements 372₁, 372₂ may be affixed to the shock-absorbing material 355 of the padding layers 348₁, 348₂ in any other suitable manner (e.g., by chemical bonding or by one or more mechanical fasteners).

Each of the low-friction elements 372₁, 372₂ of the low-friction interface 370 of the pad
10 member 344_i comprises a low-friction material 375. For example, in some embodiments, a coefficient of friction μ_e of the low-friction material 375 according to ASTM G115 - 10 (Standard Guide for Measuring and Reporting Friction Coefficients) may be no more than 0.5, in some cases no more than 0.4, in some cases no more than 0.3, in some cases no more than 0.2, in some cases no more than 0.15, in some cases no more than 0.1. The coefficient of
15 friction μ_e of the low-friction material 375 may have any other suitable value in other embodiments.

The low-friction material 375 of each of the low-friction elements 372₁, 372₂ of the low-friction interface 370 of the pad member 344_i may be implemented in any suitable way. For
20 example, in some embodiments, the low-friction material 375 may include a fluorocarbon (e.g., polytetrafluoroethylene (PTFE), such as Teflon), polyethylene, nylon, a dry lubricant (e.g., graphite, molybdenum disulfide, etc.), or any other suitable substance with a low coefficient of friction.

Therefore, in this embodiment, when the helmet 10 is subject to an impact, one or more of
25 the padding layers 348₁-348₃ of a pad member 344_i may compress under a linear impact force and/or the padding layers 348₁, 348₂ may shear relative to one another under a rotational impact force. For instance, upon a rotational impact on the helmet 10, the padding layer 348₁ can move relative to the padding layer 348₂ in a direction tangential to an angular movement
30 of the outer shell 12 due to the rotational impact. As the padding layers 348₁, 348₂ move relative to one another, the connector 350 of the pad member 344_i elastically deforms (e.g., stretches and/or bends) to accommodate this movement, while the low-friction interface 370 between the padding layers 348₁, 348₂ facilitates this movement. In this example, because of

the separateness of the pad members 344_i-344_p, the padding layers 348₁, 348₂ of the pad member 344_i can move omnidirectionally relative to one another, thereby working efficiently for various orientations of rotational impacts.

- 5 The padding layers 330₁-330_p of the inner padding 15 that are stacked and interconnected such that compression of adjacent ones of the padding layers 330₁-330_p is decoupled from shearing of these adjacent ones of the padding layers 330₁-330_p relative to one another may be implemented in various other ways in other embodiments.
- 10 As an example, in some embodiments, different ones of the pad members 344_i-344_p may be different from one another (e.g., have different shapes and/or comprise different materials). For instance, in some embodiments, the padding layers 348₁-348₃, the connector 350 and/or the low-friction interface 370 of a pad member 344_x may have different shapes and/or comprise different materials than the padding layers 348₁-348₃, the connector 350 and/or the
15 low-friction interface 370 of another pad member 344_y.

For instance, in some embodiments, as shown in Figure 77, different ones of the pad members 344_i-344_p at different locations around the helmet 10 may have different levels of compressibility and/or different levels of shearability. For example, in some embodiments, a
20 shearability of a pad member 344_x located in a lateral side of the helmet 10 may be greater than a shearability of a pad member 344_y located in a top (crown) area of the helmet 10, since rotational impacts are more likely to occur at the lateral side of the helmet 10.

In this embodiment, a stiffness of the connector 350 of the pad member 344_x located in the
25 lateral side of the helmet 10 may be lower than a stiffness of the connector 350 located in the top area of the helmet 10 to allow the padding layers 348₁-348₃ of the pad member 344_x to shear relative to one another more easily than the padding layers 348₁-348₃ of the pad member 344_y. To that end, in some embodiments, the connecting members 354₁-354₄ of the connector 350 of the pad member 344_x in the lateral side of the helmet 10 may be smaller,
30 may be fewer in number, and/or their deformable material 360 may have a greater elasticity (i.e., a lower modulus of elasticity) and/or a lower hardness than the connecting members 354₁-354₄ of the connector 350 of the pad member 344_y in the top area of the helmet 10.

Additionally or alternatively, in this embodiment, the coefficient of friction μ_i of the low-friction interface 370 between the padding layers 348₁, 348₂ of the pad member 344_x in the lateral side of the helmet 10 may be lower than the coefficient of friction μ_i of the low-friction interface 370 between the padding layers 348₁, 348₂ of the pad member 344_y in the top area of the helmet 10. As another possibility, there may be no low-friction interface such as the low-friction interface 370 between the padding layers 348₁, 348₂ of the pad member 344_y in the top area of the helmet 10, i.e., an interface between the padding layers 348₁, 348₂ of the pad member 344_x may be a direct contact of these padding layers, such that the coefficient of friction μ_i of the low-friction interface 370 between the padding layers 348₁, 348₂ of the pad member 344_x in the lateral side of the helmet 10 is lower than a coefficient of friction of the interface between the padding layers 348₁, 348₂ of the pad member 344_y in the top area of the helmet 10.

As another example, in other embodiments, the padding layers 330₁-330_p of the inner padding 15 may be implemented by a single pad member instead of the pad members 344₁-344_p that are separate from one another as considered above.

2. *External elements for rotational impact protection*

In some embodiments, the rotational impact protection system 28 of the helmet 10 may comprise one or more external elements at an external side of the outer shell 12 that help to protect against a rotational impact.

2.1 *Impact deflector*

In some embodiments, as shown in Figure 55, the external side of the outer shell 12 may comprise an impact deflector 120 to deflect a rotational impact so that an angular movement of the outer shell 12 due to the rotational impact is less than if the impact deflector 120 was omitted but the helmet 10 was otherwise identical.

In this embodiment, the impact deflector 120 comprises a low-friction material 124 that constitutes at least part of the outer surface 19 of the outer shell 12. This can make the outer

shell 12 “slippery”. For example, the low-friction material 124 may be an outer layer (e.g., a coating or film) applied on an underlying layer of the outer shell 12.

More particularly, in this embodiment, the low-friction material 124 has a coefficient of friction μ_d with an impacting object (e.g., a puck, a stick, a piece of protective equipment of another player, a board, etc.) that impacts the helmet 10 which is less than a coefficient of friction μ_s of a main material 144 of the outer shell 12 with the impacting object (i.e., the main material 144 of the outer shell 12 is the material making up a greatest proportion of the outer shell 12). For example, in some embodiments, a ratio μ_d/μ_s of the coefficient of friction μ_d of the low-friction material 124 with the impacting object over the coefficient of friction μ_s of the main material 144 of the outer shell 12 with the impacting object may be no more than 0.9, in some cases no more than 0.8, in some cases no more than 0.7, in some cases no more than 0.6, in some cases no more than 0.5, in some cases no more than 0.4, in some cases no more than 0.3, in some cases no more than 0.2, and in some cases even less. For instance, in some embodiments, a coefficient of friction μ_{d*} of the low-friction material 124 according to ASTM G115 - 10 (Standard Guide for Measuring and Reporting Friction Coefficients) may be no more than 0.5, in some cases no more than 0.4, in some cases no more than 0.3, in some cases no more than 0.2, in some cases no more than 0.15, in some cases no more than 0.1.

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For example, in this embodiment, the low-friction material 124 may include a fluorocarbon (e.g., polytetrafluoroethylene (PTFE), such as Teflon), a dry lubricant (e.g., graphite, molybdenum disulfide, etc.), or any other suitable material with a low coefficient of friction.

25 In some embodiments, with additional reference to Figure 56, the low-friction material 124 may be present only in selected areas 150₁-150_M of the outer shell 12 which are more likely to be impacted. In one example, the selected areas 150₁-150_M may include temple areas adjacent to temples of the wearer's head 11. In particular, there may be a selected area 150₁ which is a left temple area adjacent to the left temple of the wearer's head 11 and a selected area 150₂ which is a right temple area adjacent to the right temple of the wearer's head 11, both comprising the low-friction material 124 (although Figure 56 only illustrates the left temple area 150₁, the right temple area 150₂ is similar). The selected areas 150₁-150_M of the outer shell 12 may be arranged in other ways in other embodiments. For instance, as shown in

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Figure 57, a selected area 150₃ including the low-friction material 124 may be a forehead area of the helmet 10 adjacent to the forehead of the wearer's head 11.

Conversely, in some embodiments, the low-friction material 124 may not be present in
5 selected areas 151₁-151_L of the outer shell 12 which are less likely to be impacted, i.e., the
selected areas 151₁-151_L of the outer shell 12 are free of the low-friction material 124. For
example, in some embodiments, a selected area 151₁ may be a crown area facing the top of
the wearer's head 11.

10 The impact deflector 120 may be configured in various other ways in other embodiments.

For example, in other embodiments, the low-friction material 124 may constitute at least a
majority, in some cases an entirety, of the outer surface 19 of the outer shell 12.

15 By way of another example, in other embodiments, as shown in Figure 58, the impact
deflector 120 may comprise a movable interface 137 that can move relative to the outer
surface 19 of the outer shell 12 when the movable interface 137 is impacted by an impacting
object.

20 For instance, in this embodiment, the movable interface 137 comprises a rolling arrangement
140. More particularly, in this embodiment, the rolling arrangement 140 comprises a plurality
of rollers 142₁-142_R that can roll relative to the outer surface 19 of the outer shell 12 when the
rolling arrangement 140 is impacted by an impacting object. In this case, the rollers 142₁-
142_R may be elongated rollers (e.g., cylindrical rollers). In other cases, the rollers 142₁-142_R
25 may be spherical rollers (e.g., balls).

Alternatively, in other embodiments, as shown in Figure 59, the movable interface 137 may
comprise a plate 155 mounted to an underlying part 157 of the outer shell 12 by a connector
159 such that the plate 155 can move relative to the underlying part 157 of the outer shell 12
30 when the plate 155 is subject to a rotational impact. The plate 155 is mounted to the
underlying part 157 of the outer shell 12 by a connector 159 such that the plate 155 can move
relative to the underlying part 157 of the outer shell 12 when the plate 155 is subject to a
rotational impact. In this case, the connector 159 may comprise an elastic member that can

elastically stretch or otherwise deform to allow movement of the plate 155. In other cases, the connector 159 may be a mechanical link (e.g., a pivot).

2.2 *Sacrificial layer*

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In some embodiments, as shown in Figure 60, the external side of the outer shell 12 may comprise a sacrificial layer 180 configured to erode (e.g., scrape off) or be otherwise sacrificed at a point of rotational impact.

10 For instance, in this embodiment, the sacrificial layer 180 comprises a soft material 182. More particularly, in this embodiment, the soft material 182 is softer than a main material 186 of the outer shell 12 (i.e., the main material 186 of the outer shell 12 is that material making up a greatest proportion of the outer shell 12). For example, in some embodiments, a ratio H_c/H_s of a hardness H_c of the soft material 182 in durometers over a hardness H_s of the
 15 main material 186 of the outer shell 12 in durometers may be no more than 0.9, in some cases no more than 0.8, in some cases no more than 0.7, in some cases no more than 0.6, in some cases no more than 0.5, in some cases no more than 0.4, in some cases no more than 0.3, and in some cases even less. For instance, in some embodiments, the hardness H_c of the soft material 182 may be no more than a certain value in durometers. The soft material 182 may
 20 include a wax, silicone, or any other suitable material that can erode relatively easily upon being impacted.

In this embodiment, the soft material 182 is present only in selected areas 250₁-250_M of the outer shell 12 which are more likely to be impacted. For instance, the selected areas 250₁-
 25 150_M may include temple areas adjacent to temples of the wearer's head 11, as discussed previously in connection with the selected areas 150₁-150_M shown in Figure 56.

The sacrificial layer 180 may be configured in various other ways in other embodiments.

30 For example, in other embodiments, the soft material 182 may constitute at least a majority, in some cases an entirety, of the outer surface 19 of the outer shell 12.

By way of another example, in some embodiments, the sacrificial layer 180 may be replaceable. For instance, in some cases, the sacrificial layer 180 may be peelable so that it can be peeled off when damaged and replaced by a new sacrificial layer 180*. The sacrificial layer 180 may include an adhesive layer that allows it to be adhesively bonded to the outer shell 12 and removed when it is to be replaced

3. *Faceguard providing rotational impact protection*

In some embodiments, as shown in Figure 61, the faceguard 14 may be configured to absorb energy from a rotational impact.

In this embodiment, the faceguard 14 is mounted to be angularly movable (i.e., undergo an angular movement) relative to the internal surface 20 of the helmet 10 (e.g., the inner surface 34 of the inner padding 15) that contacts the wearer's head 11 in response to a rotational impact on the faceguard 14. For example, in some embodiments, the faceguard 14 may be angularly movable relative to the outer shell 12 by at least 2°, in some cases at least 5°, in some cases at least 10°, and in some cases even more. For instance, in some embodiments, the faceguard 14 may be movable (i.e., a point of the faceguard 14 may be movable) relative to the outer shell 12 by a distance (e.g., an arc length) of at least 2 mm, in some cases at least 5 mm, in some cases at least 10 mm, in some cases at least 20 mm, and in some cases even more.

In this embodiment, the faceguard 14 is mounted to the outer shell 12 by connectors 308₁, 308₂ on respective lateral sides of the faceguard 14 that allow the faceguard 14 to angularly move relative to the outer shell 12. For example, the connectors 308₁, 308₂ may comprise shock absorbers 312₁, 312₂ to absorb energy from impacts, including rotational impacts, on the faceguard 14. More particularly, in this example, each of the shock absorbers 312₁, 312₂ comprises a spring which is a resilient object that is deformable (i.e., changeable in configuration) such that it changes in configuration under load and recovers its initial configuration when the load is removed. The spring may be an elastomeric spring (e.g., a rubber spring), a coil spring (e.g., a metallic or polymeric coil spring), a leaf spring, a fluid spring (i.e., a spring including a liquid or gas contained in a container such as a cylinder or a bellows and variably compressed) such as a gas spring, or any other resilient object that

changes in configuration under load and recovers its initial configuration when the load is removed.

The connectors 308₁, 308₂ may be such that a transversal displacement capability of the faceguard 14 relative to the internal surface 20 of the helmet 10 is greater than a longitudinal displacement capability of the faceguard 14 relative to the internal surface 20 of the helmet 10. The faceguard's transversal displacement capability is a capability of the faceguard 14 to move relative to the internal surface 20 of the helmet 10 in a direction parallel to the helmet's transversal (i.e., left-right) axis LRA, whereas the faceguard's longitudinal displacement capability is a capability of the faceguard 14 to move relative to the internal surface 20 of the helmet 10 in a direction parallel to the helmet's longitudinal (i.e., front-back) axis FBA.

The faceguard 14 may be prevented from contacting the wearer's face when the outer shell 12 angularly moves in response to a rotational impact.

The faceguard 14 may be configured in various other ways to provide rotational impact protection in other embodiments.

4. *Multi-level rotational impact protection*

In some embodiments, as shown in Figure 62, the rotational impact protection system 28 of the helmet 10 may comprise a plurality of distinct rotational impact protection mechanisms 500₁-500_R to provide "multi-level" rotational impact protection. In response to a rotational impact, each of the rotational impact protection mechanisms 500₁-500_R absorbs some energy from the rotational impact such that, cumulatively, this reduces rotational energy transmitted to the wearer's head 11 and, therefore, an angular acceleration of the wearer's head 11 by a greater amount than that which would be achieved by any of the rotational impact protection mechanisms 500₁-500_R acting alone.

For instance, in some embodiments, each of the rotational impact protection mechanisms 500₁-500_R may include any feature considered herein in sections 1 to 3. For example, in some cases, a first one of the rotational impact protection mechanisms 500₁-500_R may include an internal rotational impact protection mechanism having any feature considered herein in

section 1 and a second one of the rotational impact protection mechanisms 500₁-500_R may include an external rotational impact protection mechanism having any feature considered herein in section 2. As another example, in some cases, a first one of the rotational impact protection mechanisms 500₁-500_R may include an internal or external rotational impact protection mechanism having any feature considered herein in section 1 or 2 and a second one of the rotational impact protection mechanisms 500₁-500_R may relate to the faceguard 14 and have any feature considered herein in section 3.

In some embodiments, a first rotational impact protection mechanism 500_i may be in series or cascading with a second rotational impact protection mechanism 500_j such that, in response to a rotational impact, an action of the first rotational impact protection mechanism 500_i induces an action of the rotational impact protection mechanism 500_j. For example, in some embodiments, a movement of a component of the first rotational impact protection mechanism 500_i induces a movement of a component of the second rotational impact protection mechanism 500_j.

For example, in some embodiments, as illustrated in Figure 63, the arrangement of shock absorbers 65₁-65_N which are deformable in response to a rotational impact on the helmet 10 and discussed above are combined with the impact deflector 120 also discussed above. The rotational impact protection system 28 in this case thus includes two rotational impact protection mechanisms 500₁ and 500₂, where the arrangement of shock absorbers 65₁-65_N is the first rotational impact protection mechanism 500₁ and the impact deflector 120 is the second rotational impact protection mechanism 500₂. In this case, when a rotational impact force impacts the impact deflector 120, the impact deflector 120 will deflect some of the impact force. Then, part of the impact force not deflected will be absorbed by the shock absorbers 61₁-61_N that deform.

Although not illustrated in Figure 63, the faceguard 14 implementing a rotational impact protection mechanism, as discussed above in section 3, could also be applied as a third rotational impact protection mechanisms 500₃ to the shock absorbers 65₁-65_N (i.e., the first rotational impact protection mechanism 500₁) and the impact deflector 120 (i.e., the second rotational impact protection mechanism 500₂), of the example discussed above.

As another example, in some embodiments, as illustrated in Figure 64, the floating liner 450 which is movable relative to the inner padding 15 and outer shell 12 and discussed above is combined with the impact deflector 120 also discussed above. In this case, the rotational impact protection system 28 thus includes two rotational impact protection mechanisms 500₁ and 500₂, where the floating liner 450 is the first rotational impact protection mechanism 500₁ and the impact deflector 120 is the second rotational impact protection mechanism 500₂.

Again, although not illustrated in Figure 64, the faceguard 14 implementing a rotational impact protection mechanism, as discussed above in section 3, could also be applied as a third rotational impact protection mechanisms 500₃ to the floating liner 450 (i.e., the first rotational impact protection mechanism 500₁) and the impact deflector 120 (i.e., the second rotational impact protection mechanism 500₂), of the example discussed above.

The rotational impact protection mechanisms 500₁-500_R may be configured in various other ways in other embodiments.

Any feature of any embodiment discussed herein may be combined with any feature of any other embodiment discussed herein in some examples of implementation.

Although in embodiments considered above the helmet 10 is a hockey helmet for protecting the head of a hockey player, in other embodiments, a helmet constructed using principles described herein in respect of the helmet 10 may be another type of sport helmet. For instance, a helmet constructed using principles described herein in respect of the helmet 10 may be for protecting the head of a player of another type of contact sport (sometimes referred to as “full-contact sport” or “collision sport”) in which there are significant impact forces on the player due to player-to-player and/or player-to-object contact. For example, in one embodiment, a helmet constructed using principles described herein in respect of the helmet 10 may be a lacrosse helmet for protecting the head of a lacrosse player. As another example, in one embodiment, a helmet constructed using principles described herein in respect of the helmet 10 may be a football helmet for protecting the head of a football player. As another example, in one embodiment, a helmet constructed using principles described herein in respect of the helmet 10 may be a baseball helmet for protecting the head of a baseball player (e.g., a batter or catcher). Furthermore, a helmet constructed using principles

described herein in respect of the helmet 10 may be for protecting the head of a wearer involved in a sport other than a contact sport (e.g., bicycling, skiing, snowboarding, horseback riding or another equestrian activity, etc.).

- 5 Also, while in the embodiments considered above the helmet 10 is a sport helmet, a helmet constructed using principles described herein in respect of the helmet 10 may be used in an activity other than sport in which protection against head injury is desired. For example, in one embodiment, a helmet constructed using principles described herein in respect of the helmet 10 may be a motorcycle helmet for protecting the head of a wearer riding a
10 motorcycle. As another example, in one embodiment, a helmet constructed using principles described herein in respect of the helmet 10 may be a industrial or military helmet for protecting the head of a wearer in an industrial or military application.

- Although various embodiments and examples have been presented, this was for the purpose
15 of describing, but not limiting, the invention. Various modifications and enhancements will become apparent to those of ordinary skill in the art and are within the scope of the invention, which is defined by the appended claims.

CLAIMS

1. A helmet for protecting a head of a wearer, the helmet comprising:
 - 5 an outer shell; and
 - inner padding connected to the outer shell, the inner padding configured to be disposed between the outer shell and the wearer's head, the inner padding comprising a plurality of pads separate from one another, each pad comprising a plurality of padding layers that overlap one another and are arranged such that adjacent ones of the padding layers of the
 - 10 pad are movable relative to one another in response to a rotational impact on the outer shell, wherein:
 - the pad comprises a low-friction interface between the adjacent ones of the padding layers of the pad to facilitate movement of the adjacent ones of the padding layers of the pad relative to one another;
 - 15 the low-friction interface of the pad is between a first one of the padding layers of the pad and a second one of the padding layers of the pad; and
 - the low-friction interface of the pad is configured such that a coefficient of friction between the first one of the padding layers of the pad and the second one of the padding layers of the pad is lower than a coefficient of friction between a shock-absorbing
 - 20 material of the first one of the padding layers of the pad and a shock-absorbing material of the second one of the padding layers of the pad.
2. The helmet of claim 1, wherein the adjacent ones of the padding layers of the pad are movable relative to one another in a direction tangential to angular movement of the outer
- 25 shell in response to the rotational impact.
3. The helmet of claim 1, wherein the adjacent ones of the padding layers of the pad are shearable relative to one another in response to the rotational impact.
- 30 4. The helmet of claim 3, wherein the adjacent ones of the padding layers of the pad are stacked and interconnected such that compression of the adjacent ones of the padding layers of the pad is decoupled from shearing of the adjacent ones of the padding layers of the pad relative to one another.

5. The helmet of claim 1, wherein the adjacent ones of the padding layers of the pad are movable omnidirectionally relative to one another in response to the rotational impact.
- 5 6. The helmet of claim 1, wherein the pad comprises a connector interconnecting the adjacent ones of the padding layers of the pad.
7. The helmet of claim 6, wherein the connector of the pad is elastically deformable to allow the adjacent ones of the padding layers of the pad to move relative to one another in response to the rotational impact.
- 10
8. The helmet of claim 7, wherein the connector of the pad is at least one of elastically stretchable and elastically bendable to allow the adjacent ones of the padding layers of the pad to move relative to one another in response to the rotational impact.
- 15
9. The helmet of claim 7, wherein the connector of the pad comprises elastomeric material.
10. The helmet of claim 6, wherein the connector of the pad is elongated in a direction from the first one of the padding layers of the pad towards the second one of the padding layers of the pad.
- 20
11. The helmet of claim 10, wherein the connector of the pad comprises: an elongate portion that is elongated in the direction from the first one of the padding layers of the pad towards the second one of the padding layers of the pad; and an enlarged portion that is larger than the elongate portion of the connector of the pad in a direction transversal to the direction from the first one of the padding layers of the pad towards the second one of the padding layers of the pad.
- 25
12. The helmet of claim 11, wherein: the enlarged portion of the connector of the pad is a first enlarged portion of the connector of the pad; the connector of the pad comprises a second enlarged portion that is larger than the elongate portion of the connector of the pad in a direction transversal to the direction from the first one of the padding layers of the pad towards the second one of the padding layers of the pad; and the adjacent ones of
- 30

the padding layers of the pad are disposed between the first enlarged portion and the second enlarged portion of the connector of the pad.

13. The helmet of claim 6, wherein a third one of the padding layers of the pad is secured to
5 the second one of the padding layers of the pad other than by the connector of the pad.

14. The helmet of claim 13, wherein the third one of the padding layers of the pad is adhesively bonded to the second one of the padding layers of the pad.

10 15. The helmet of claim 6, wherein an end of the connector of the pad is disposed between a third one of the padding layers of the pad and the second one of the padding layers of the pad.

16. The helmet of claim 15, wherein the end of the connector of the pad is concealed between
15 the third one of the padding layers of the pad and the second one of the padding layers of the pad.

17. The helmet of claim 6, wherein the connector of the pad extends through the adjacent ones of the padding layers of the pad.

20 18. The helmet of claim 6, wherein the connector of the pad comprises a plurality of connecting members separate from one another.

19. The helmet of claim 6, wherein a modulus of elasticity of the connector of the pad is
25 different from a modulus of elasticity of a given one of the padding layers of the pad.

20. The helmet of claim 19, wherein the modulus of elasticity of the connector of the pad is less than the modulus of elasticity of the given one of the padding layers of the pad.

30 21. The helmet of claim 6, wherein the connector of the pad is configured to suspend the first one of the padding layers of the pad between the second one of the padding layers of the pad and the wearer's head.

22. The helmet of claim 1, wherein a third one of the padding layers of the pad is configured to remain stationary relative to the second one of the padding layers of the pad in response to the rotational impact.
- 5 23. The helmet of claim 1, wherein the shock-absorbing material of the first one of the padding layers of the pad is a first padding material and the shock-absorbing material of the second one of the padding layers of the pad is a second padding material different from the first padding material.
- 10 24. The helmet of claim 23, wherein the first padding material comprises a first foam and the second padding material comprises a second foam different from the first foam.
- 15 25. The helmet of claim 24, wherein a third one of the padding layers of the pad comprises a third padding material different from the first padding material and the second padding material.
26. The helmet of claim 23, wherein the first padding material comprises foam and the second padding material comprises a material other than foam.
- 20 27. The helmet of claim 23, wherein the first padding material comprises foam and the second padding material comprises expanded polymeric microspheres.
- 25 28. The helmet of claim 1, wherein a compressibility of a padding material of a given one of the padding layers of the pad is greater than a shearability of the padding material of the given one of the padding layers of the pad, such that the padding material of the given one of the padding layers of the pad deforms by compression more easily than by shearing.
- 30 29. The helmet of claim 1, wherein given ones of the padding layers of the pad differ in stiffness from one another.

30. The helmet of claim 29, wherein the first one of the padding layers of the pad is stiffer than the second one of the padding layers of the pad that is configured to be closer to the wearer's head than the first one of the padding layers of the pad.
- 5 31. The helmet of claim 30, wherein the second one of the padding layers of the pad is stiffer than a third one of the padding layers of the pad that is configured to be closer to the wearer's head than the second one of the padding layers of the pad.
- 10 32. The helmet of claim 1, wherein the first one of the padding layers of the pad is a main shock absorption layer of the pad and the second one of the padding layers of the pad configured to be closer to the wearer's head than the main shock absorption layer of the pad is a comfort layer of the pad.
- 15 33. The helmet of claim 32, wherein a third one of the padding layers of the pad is an intermediate layer of the pad disposed between the main shock absorption layer of the pad and the comfort layer of the pad.
- 20 34. The helmet of claim 1, wherein given ones of the padding layers of the pad have different shapes from one another.
- 25 35. The helmet of claim 1, wherein given ones of the pads have different shapes from one another.
- 30 36. The helmet of claim 1, wherein the outer shell comprises a first shell member and a second shell member movable relative to one another to adjust a size of the helmet.
37. The helmet of claim 36, wherein respective ones of the pads are secured to different ones of the first shell member and the second shell member to move relative to one another when the first shell member and the second shell member are moved relative to one another to adjust the size of the helmet.
38. The helmet of claim 1, wherein the helmet is a hockey helmet.

39. The helmet of claim 1, wherein the second one of the padding layers of the pad comprises a comfort layer for contacting the wearer's head when the helmet is worn.

40. The helmet of claim 1, wherein: the low-friction interface of the pad comprises a first low-friction element of the pad and a second low-friction element of the pad; and a coefficient of friction between the first low-friction element of the pad and the second low-friction element of the pad is lower than a coefficient of friction between the shock-absorbing material of the first one of the padding layers of the pad and the shock-absorbing material of the second one of the padding layers of the pad.

41. The helmet of claim 1, wherein the low-friction interface of the pad comprises at least one low-friction element, each low-friction element including at least one of a fluorocarbon, polyethylene, nylon, or a dry lubricant.

42. A helmet for protecting a head of a wearer, the helmet comprising:
an outer shell; and
inner padding connected to the outer shell, the inner padding configured to be disposed between the outer shell and the wearer's head, the inner padding comprising a plurality of pads separate from one another, each pad comprising a plurality of padding layers that overlap one another and are arranged such that adjacent ones of the padding layers of the pad are movable relative to one another in response to a rotational impact on the outer shell, wherein, for each pad of the plurality of pads separate from one another, the plurality of padding layers of the pad comprises a comfort layer for contacting the wearer's head when the helmet is worn.

43. The helmet of claim 42, wherein the adjacent ones of the padding layers of the pad are movable relative to one another in a direction tangential to angular movement of the outer shell in response to the rotational impact.

44. The helmet of claim 42, wherein the adjacent ones of the padding layers of the pad are shearable relative to one another in response to the rotational impact.

45. The helmet of claim 44, wherein the adjacent ones of the padding layers of the pad are stacked and interconnected such that compression of the adjacent ones of the padding layers of the pad is decoupled from shearing of the adjacent ones of the padding layers of the pad relative to one another.
- 5
46. The helmet of claim 42, wherein the adjacent ones of the padding layers of the pad are movable omnidirectionally relative to one another in response to the rotational impact.
47. The helmet of claim 42, wherein the pad comprises elastic material retaining the adjacent layers of the pad together and stretchable to allow the adjacent layers of the pad to move relative to one another in response to the rotational impact on the outer shell.
- 10
48. The helmet of claim 42, wherein the pad comprises a low-friction interface between the adjacent ones of the padding layers of the pad to facilitate movement of the adjacent ones of the padding layers of the pad relative to one another.
- 15
49. The helmet of claim 48, wherein the low-friction interface of the pad is between a main shock absorption layer of the pad and the comfort layer of the pad.
- 20
50. The helmet of claim 48, wherein the low-friction interface of the pad comprises at least one low-friction element, each low-friction element including at least one of a fluorocarbon, polyethylene, nylon, or a dry lubricant.
51. The helmet of claim 42, wherein given ones of the padding layers of the pad have different shapes from one another.
- 25
52. The helmet of claim 42, wherein given ones of the pads have different shapes from one another.
- 30
53. The helmet of claim 42, wherein the outer shell comprises a first shell member and a second shell member movable relative to one another to adjust a size of the helmet.

54. The helmet of claim 53, wherein respective ones of the pads are secured to different ones of the first shell member and the second shell member to move relative to one another when the first shell member and the second shell member are moved relative to one another to adjust the size of the helmet.

5

55. The helmet of claim 42, wherein the helmet is a hockey helmet.

56. A helmet for protecting a head of a wearer, the helmet comprising:

an outer shell; and

10 inner padding connected to the outer shell, the inner padding configured to be disposed between the outer shell and the wearer's head, the inner padding comprising a plurality of protective members separate from one another, each protective member comprising a plurality of layers that overlap one another and are arranged such that adjacent ones of the layers of the protective member are shearable relative to one another and slidable against
15 one another in response to a rotational impact on the outer shell.

57. The helmet of claim 56, wherein the adjacent ones of the layers of the protective member respectively comprise low-friction elements configured to facilitate sliding of the low-friction elements against one another in response to the rotational impact on the outer
20 shell.

58. The helmet of claim 56, wherein each of the low-friction elements includes at least one of a fluorocarbon, polyethylene, nylon, or a dry lubricant.

25 59. The helmet of claim 56, wherein the protective member comprises elastic material retaining the layers of the protective member together and stretchable to allow the layers of the protective member to shear relative to one another and slide against one another in response to the rotational impact on the outer shell.

30 60. The helmet of claim 56, wherein a given one of the layers of the protective member comprises a shock-absorbing material.

61. The helmet of claim 60, wherein the shock-absorbing material comprises foam.

62. The helmet of claim 60, wherein the shock-absorbing material comprises fluid.
- 5 63. The helmet of claim 60, wherein the given one of the layers of the protective member comprises a low-friction element connected to the shock-absorbing material.
64. The helmet of claim 56, wherein each of the layers of the protective member comprises a shock-absorbing material.
- 10 65. The helmet of claim 56, wherein a material of a first one of the layers of the protective member is different from a material of a second one of the layers of the protective member.
- 15 66. The helmet of claim 56, wherein the adjacent ones of the layers of the protective member are shearable omnidirectionally relative to one another.
- 20 67. The helmet of claim 56, wherein a left one of the protective members is disposed on a left side of the helmet and a right one of the protective members is disposed on a right side of the helmet.
- 25 68. The helmet of claim 67, wherein the left one of the protective members is a first left one of the protective members, the right one of the protective members is a first right one of the protective members, a second left one of the protective members is disposed on the left side of the helmet, and a second right one of the protective members is disposed on the right side of the helmet.
69. The helmet of claim 56, wherein the outer shell comprises a first shell member and a second shell member movable relative to one another to adjust a size of the helmet.
- 30 70. The helmet of claim 69, wherein respective ones of the protective members are secured to different ones of the first shell member and the second shell member to move relative to one another when the first shell member and the second shell member are moved relative to one another to adjust the size of the helmet.

71. The helmet of claim 56, wherein the helmet is a hockey helmet.

72. A helmet for protecting a head of a wearer, the helmet comprising:

- 5 - an outer shell; and
- inner padding configured to be disposed between the outer shell and the wearer's head, the inner padding comprising:
 - i) an outer part connected to the outer shell;
 - ii) an inner part that faces the wearer's head; and
 - 10 iii) a plurality of sliding interfaces separate from one another and arranged between the outer part and the inner part of the inner padding such that the outer part and the inner part of the inner padding are shearable relative to one another by sliding against one another in response to a rotational impact on the outer shell, wherein the inner part of the inner padding comprises a
 - 15 comfort layer for contacting the wearer's head when the helmet is worn, the comfort layer comprising a plurality of comfort pads separate from one another, the plurality of sliding interfaces separate from one another being arranged between the plurality of comfort pads and the outer part of the inner padding, such that each comfort pad of the plurality of comfort pads separate
 - 20 from one another is shearable relative to the outer part of the inner padding by sliding against the outer part of the inner padding in response to the rotational impact on the outer shell.

73. The helmet of claim 72, further comprising a plurality of connectors, including at least
25 one connector for each sliding interface, the plurality of connectors interconnecting the inner and outer parts of the inner padding and being elastically deformable to allow the inner and outer parts of the inner padding to slide against one another in response to a rotational impact on the outer shell.

30 74. The helmet of claim 72, wherein a shock-absorbing material of the inner part of the inner padding is a first padding material and a shock-absorbing material of the outer part of the inner padding is a second padding material different from the first padding material.

75. The helmet of claim 72, wherein each comfort pad of the plurality of comfort pads separate from one another is slidably connected to the outer part of the inner padding by at least one of the deformable connectors of the plurality of deformable connectors.
- 5 76. The helmet of claim 72, wherein given ones of the comfort pads have different shapes from one another.
77. The helmet of claim 75, wherein, for each comfort pad of the plurality of comfort pads separate from one another, the at least one connector slidably connecting the comfort pad to the outer part of the inner padding interconnects the comfort pad and the outer part of the inner padding such that the comfort pads are each slidable relative to the outer part of the inner padding independent of one another.
- 10
78. The helmet of claim 72, wherein each sliding interface of the plurality of sliding interfaces separate from one another comprises a low-friction interface, configured such that a coefficient of friction between the outer part of the inner padding and the inner part of the inner padding at the sliding interface is lower than a coefficient of friction between a shock-absorbing material of the outer part of the inner padding and a shock-absorbing material of the inner part of the inner padding, to facilitate movement of the inner and outer parts of the inner padding relative to one another.
- 15
- 20
79. The helmet of claim 78 wherein:
- each sliding interface comprises a first low-friction element coupled to the outer part of the inner padding and a second low-friction element coupled to the inner part of the inner padding; and
- 25
- a coefficient of friction between the first low-friction element and the second low-friction element is lower than a coefficient of friction between the shock-absorbing material of the outer part of the inner padding and the shock-absorbing material of the inner part of the inner padding.
- 30
80. The helmet of claim 79, wherein the first low-friction element coupled to the outer part of the inner padding has a generally flat circular disk shape.

81. The helmet of claim 78, wherein each sliding interface comprises at least one low-friction element, each low-friction element including at least one of a fluorocarbon, polyethylene, nylon, or a dry lubricant.
- 5 82. The helmet of claim 72, wherein the outer part of the inner padding comprises a plurality of outer pads separate from one another.
83. The helmet of claim 82, wherein the outer shell comprises a first shell member and a second shell member movable relative to one another to adjust a size of the helmet.
- 10 84. The helmet of claim 83, wherein respective ones of the outer pads are secured to different ones of the first shell member and the second shell member to move relative to one another when the first shell member and the second shell member are moved relative to one another to adjust the size of the helmet.
- 15 85. The helmet of claim 72, wherein the helmet is a hockey helmet.
86. A helmet for protecting a head of a wearer, the helmet comprising:
- an outer shell;
 - 20 - main shock absorption padding connected to the outer shell;
 - comfort padding configured to be arranged between the main shock absorption padding and the wearer's head when the helmet is worn, the comfort padding comprising a plurality of comfort pads for contacting the wearer's head when the helmet is worn, the comfort pads being separate from one another and separately
 - 25 connected to the main shock absorption padding such that each comfort pad is independently movable relative to the outer shell by sliding against the main shock absorption padding in response to a rotational impact on the outer shell.
87. The helmet of claim 86, wherein each comfort pad of the plurality of comfort pads
- 30 separate from one another is separately connected to the main shock absorption padding by at least one deformable connector that is elastically deformable to allow the comfort pad to slide against the main shock absorption padding in response to a rotational impact on the outer shell

88. The helmet of claim 86, wherein given ones of the comfort pads have different shapes from one another.

5 89. The helmet of claim 87, wherein between each comfort pad and the main shock absorption padding is a low-friction interface configured such that a coefficient of friction between the main shock absorption padding and a given comfort pad is lower than a coefficient of friction between a shock-absorbing material of the main shock absorption padding and a shock-absorbing material of the comfort pad.

10

90. The helmet of claim 89 wherein, for each comfort pad:

the low-friction interface between the comfort pad and the main shock absorption padding comprises a first low-friction element coupled to the main shock absorption padding and a second low-friction element coupled to the comfort pad; and

15 a coefficient of friction between the first low-friction element and the second low-friction element is lower than a coefficient of friction between the shock-absorbing material of the main shock absorption padding and the shock-absorbing material of the comfort pad.

20 91. The helmet of claim 90, wherein the first low-friction element coupled to the main shock absorption padding has a generally flat circular disk shape.

92. The helmet of claim 89, wherein each low-friction interface comprises at least one low-friction element, each low-friction element including at least one of a fluorocarbon,
25 polyethylene, nylon, or a dry lubricant.

93. The helmet of claim 86, wherein the main shock absorption padding comprises a plurality of main shock absorption pads separate from one another.

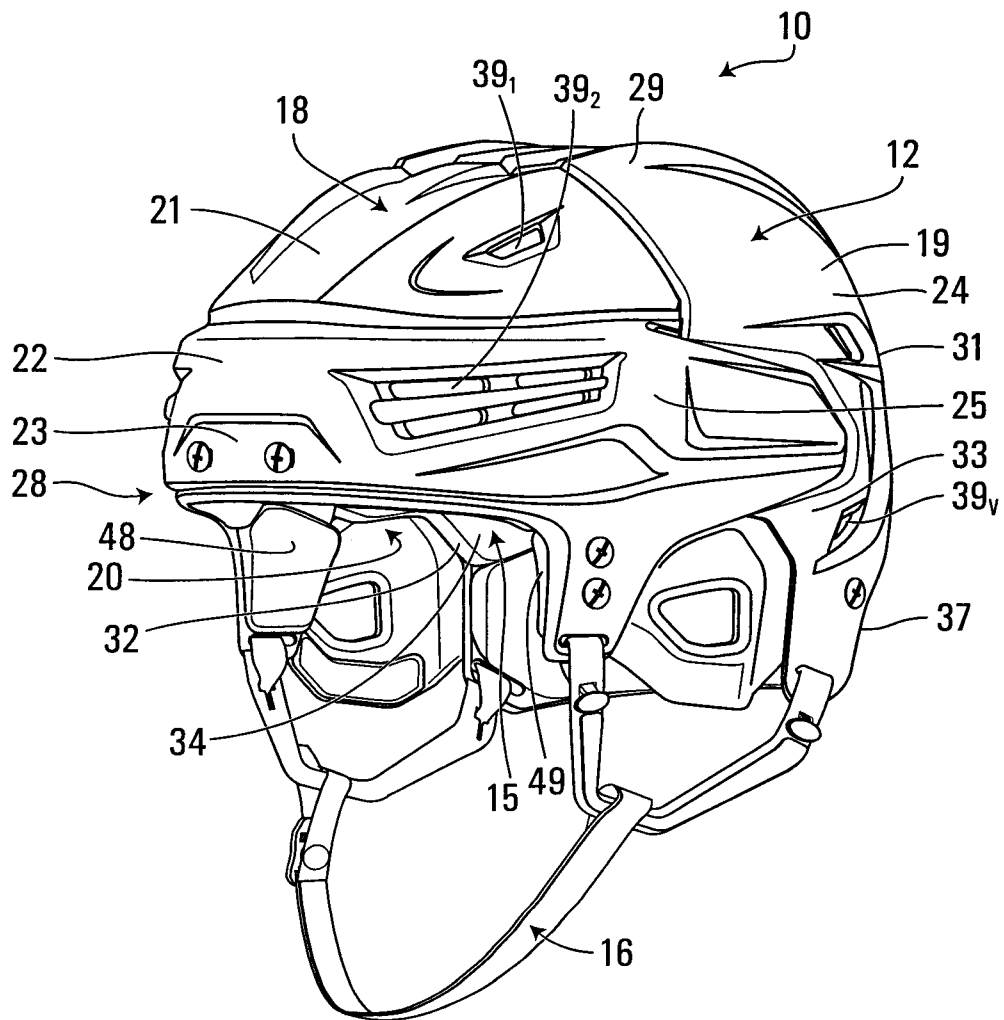
30 94. The helmet of claim 93, wherein the outer shell comprises a first shell member and a second shell member movable relative to one another to adjust a size of the helmet, wherein respective ones of the main shock absorption pads are secured to different ones of the first shell member and the second shell member to move relative to one another

when the first shell member and the second shell member are moved relative to one another to adjust the size of the helmet.

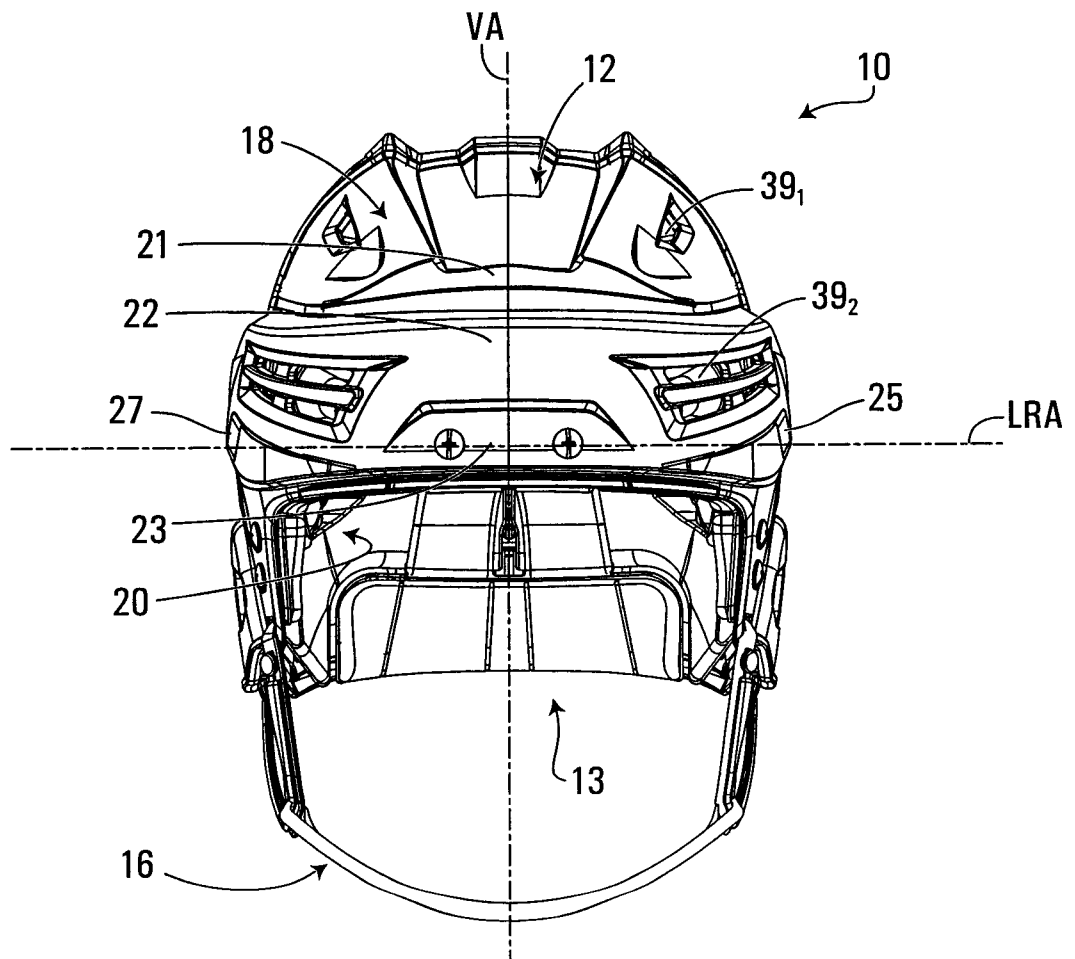
95. The helmet of claim 86, wherein the helmet is a hockey helmet.

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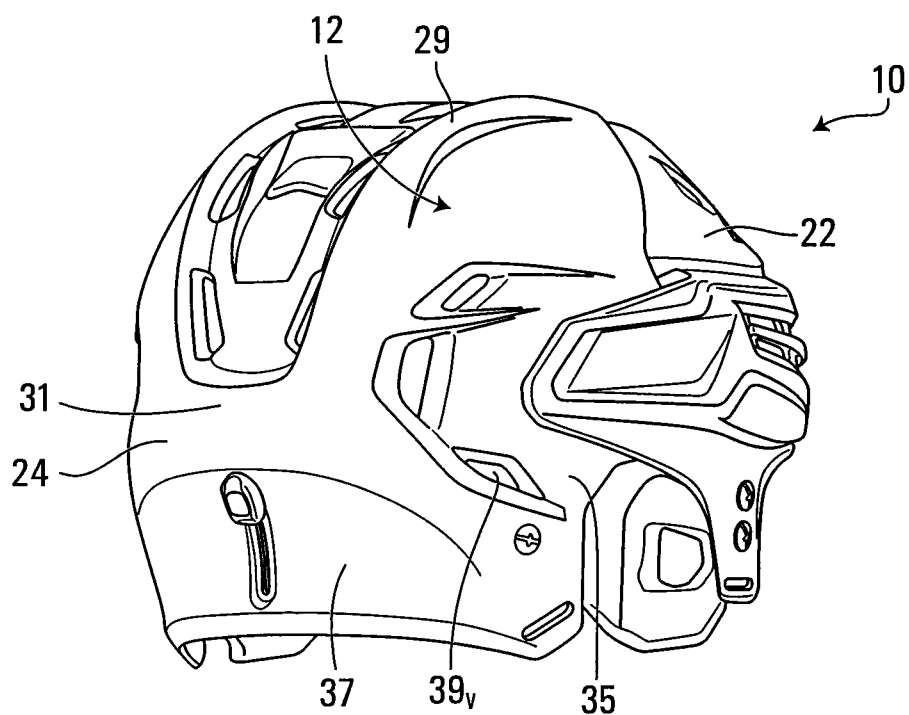
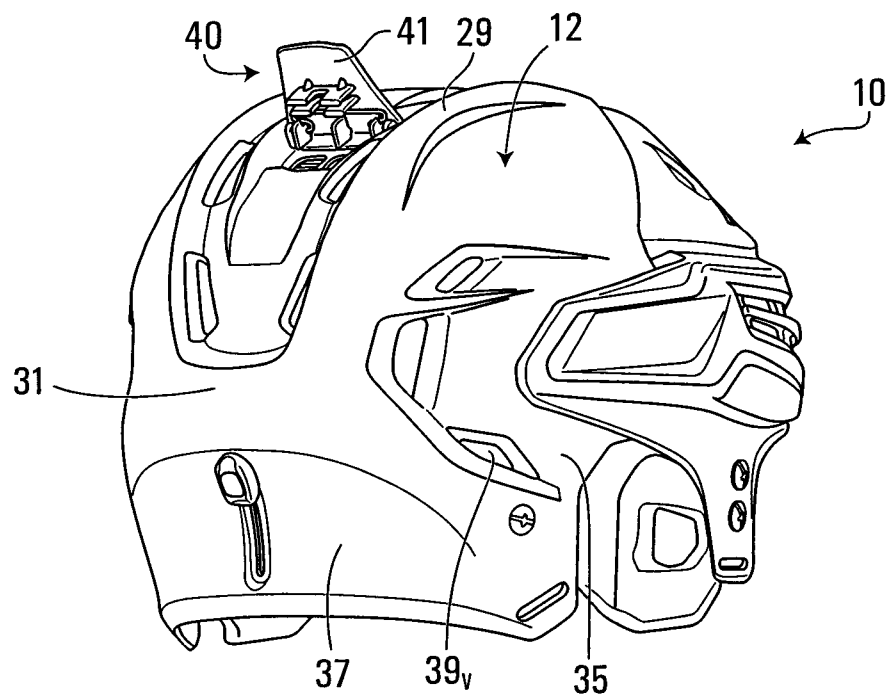
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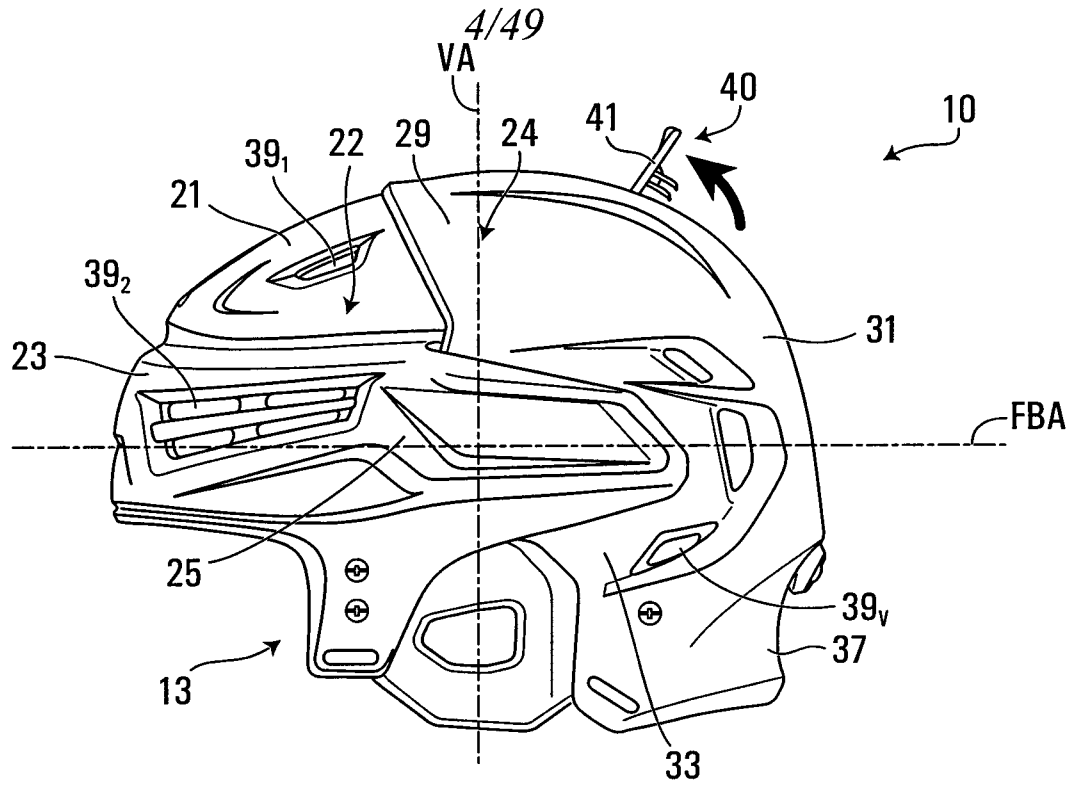
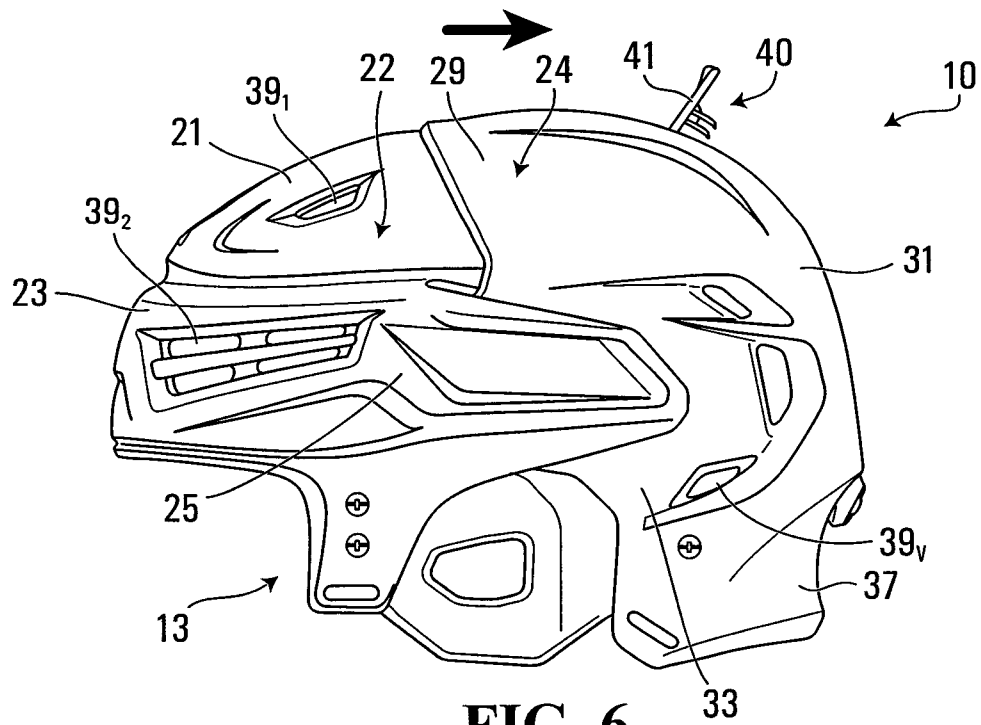
**FIG. 1**

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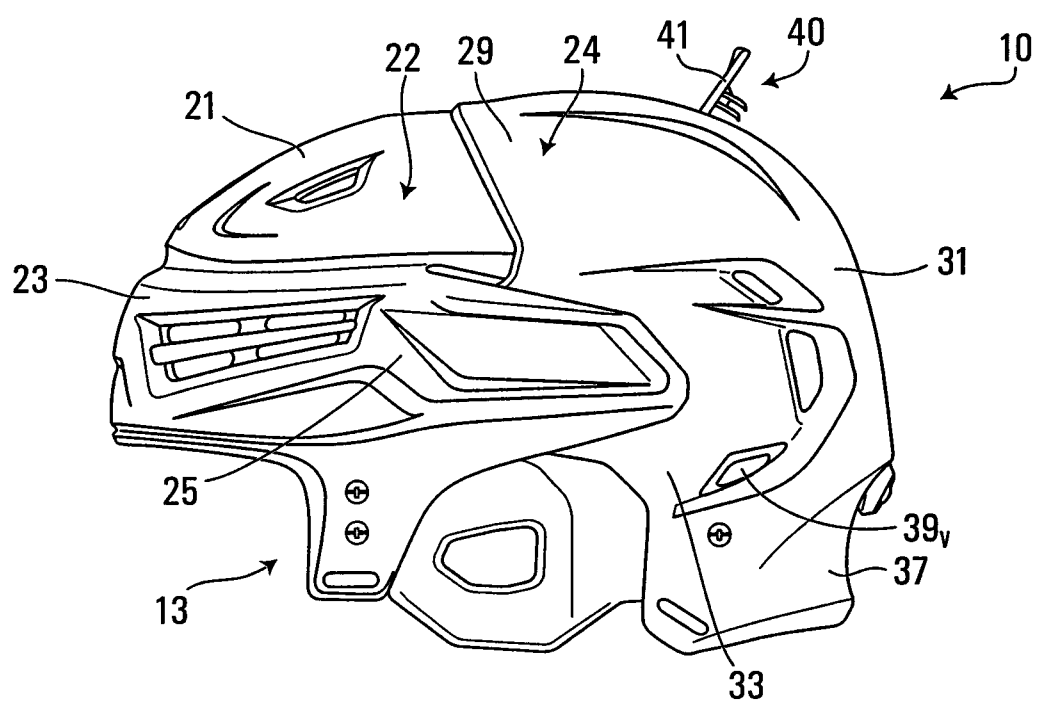
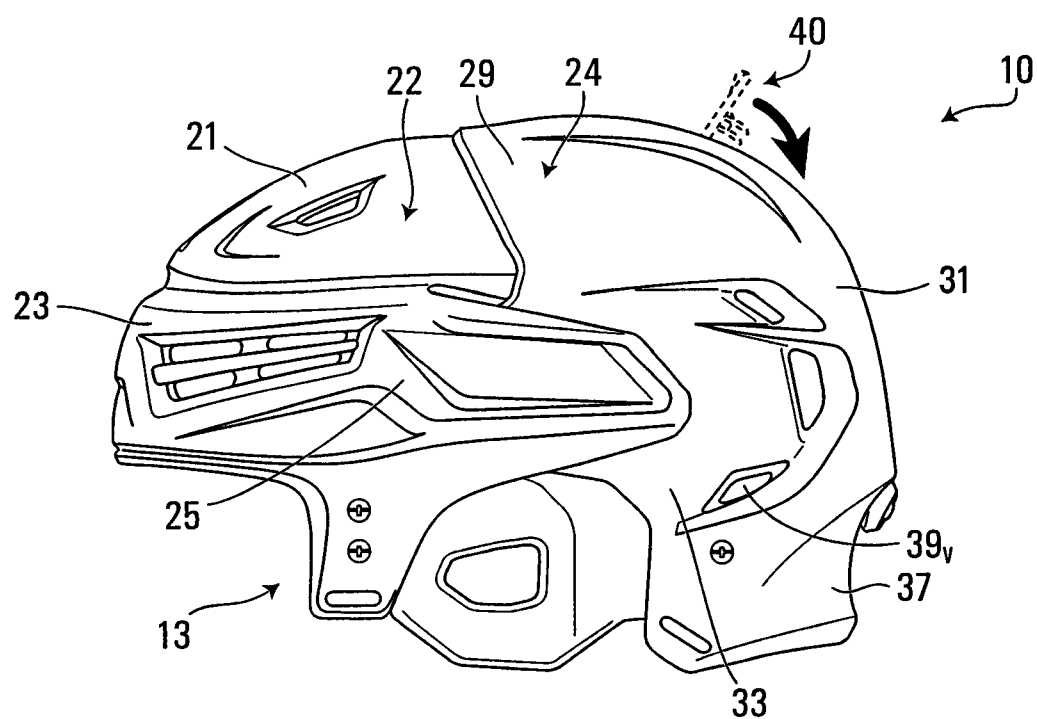
**FIG. 2**

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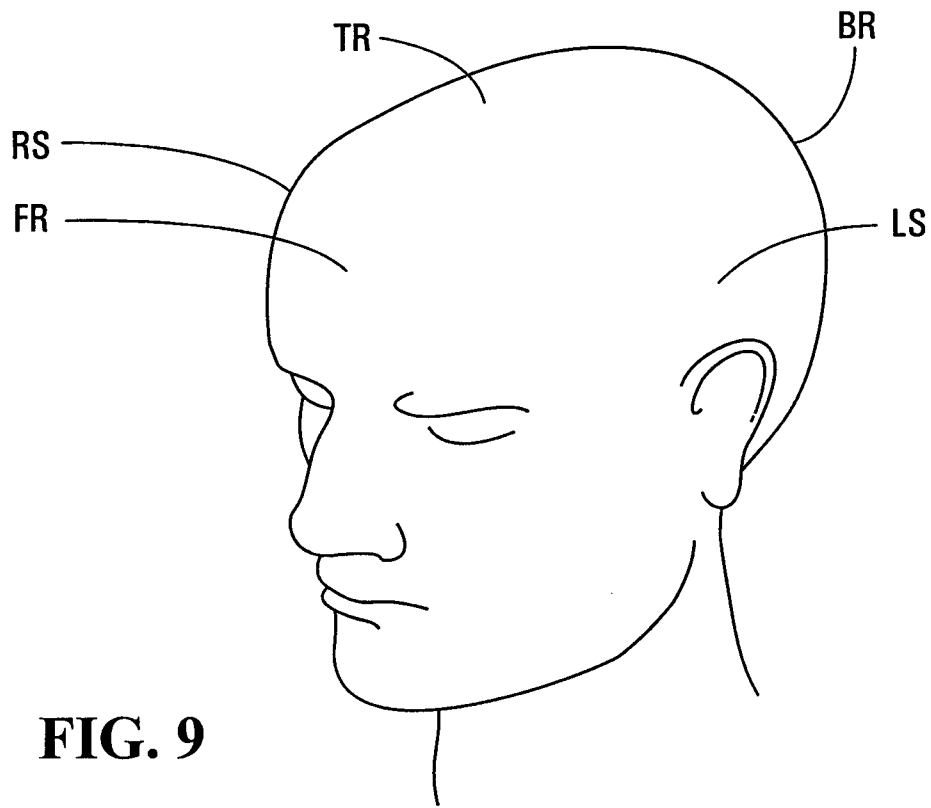
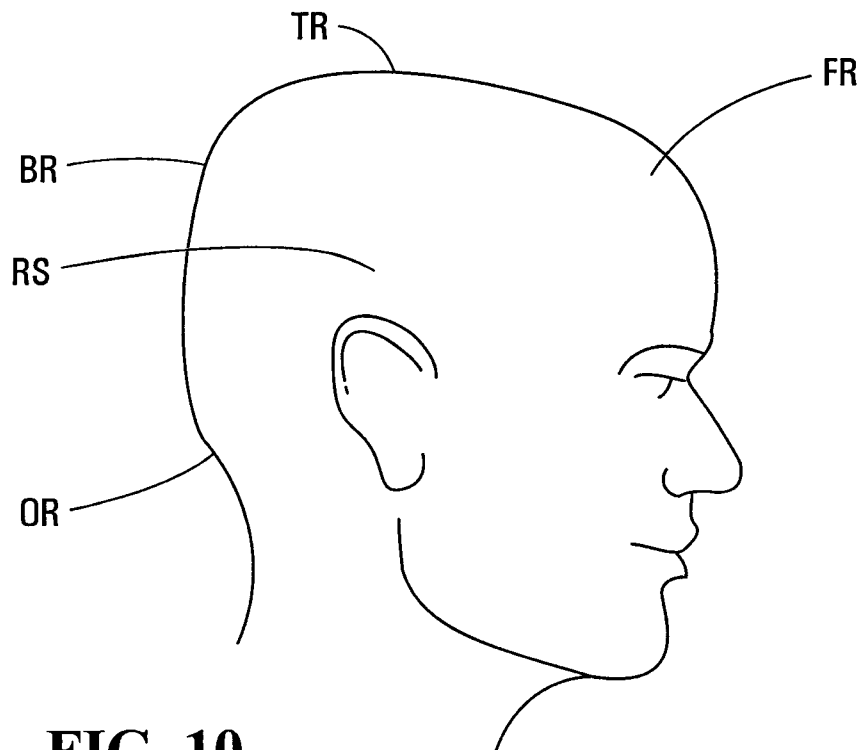
**FIG. 3****FIG. 4**

**FIG. 5****FIG. 6**

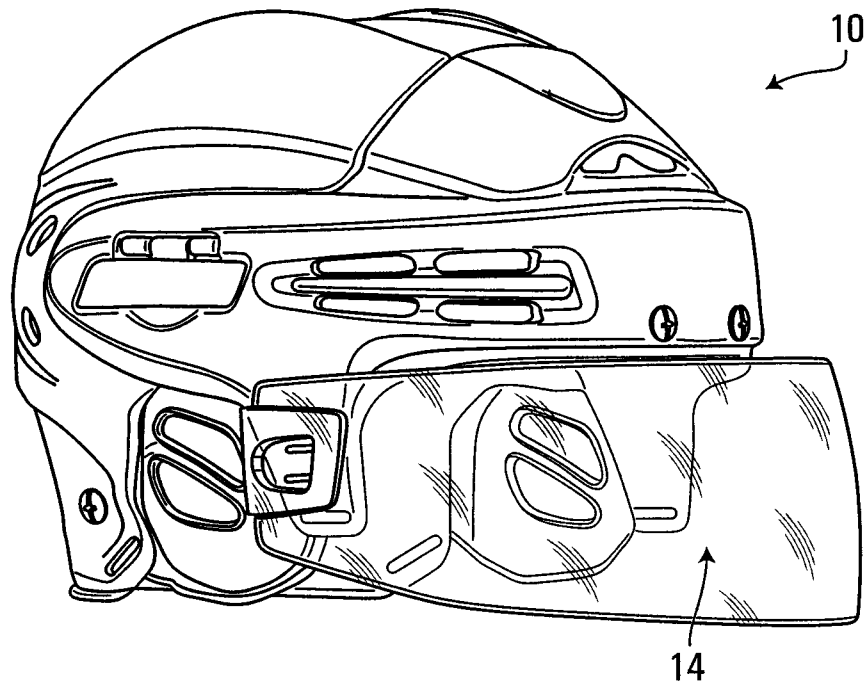
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**FIG. 7****FIG. 8**

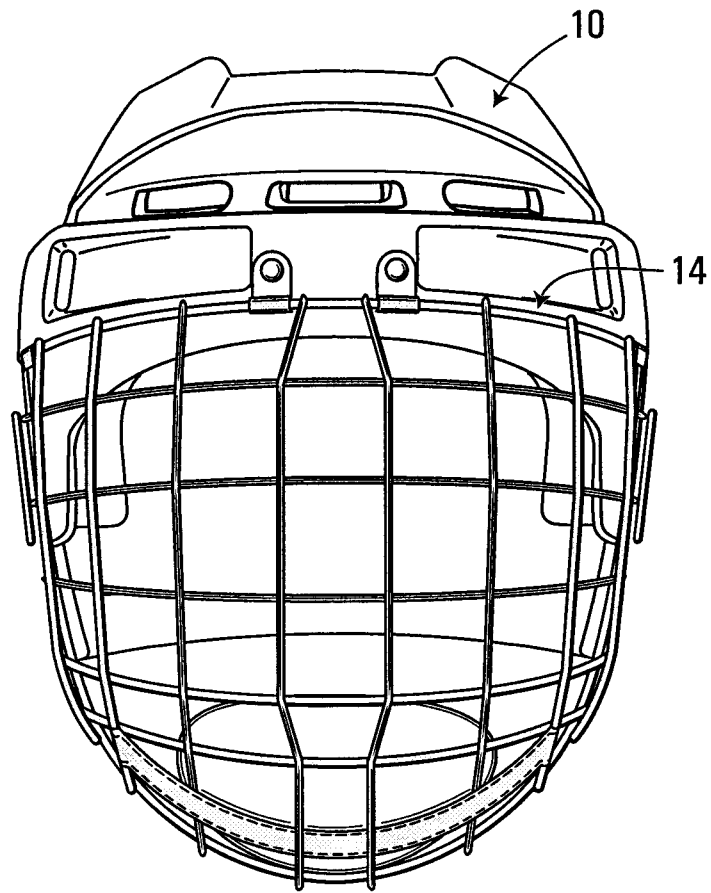
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**FIG. 9****FIG. 10**

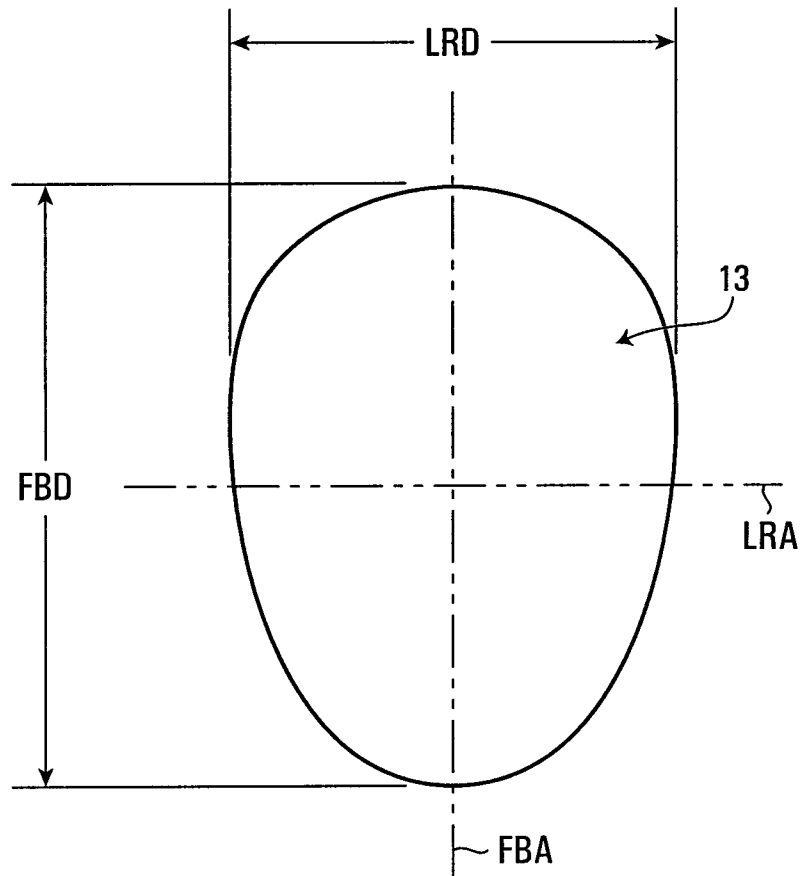
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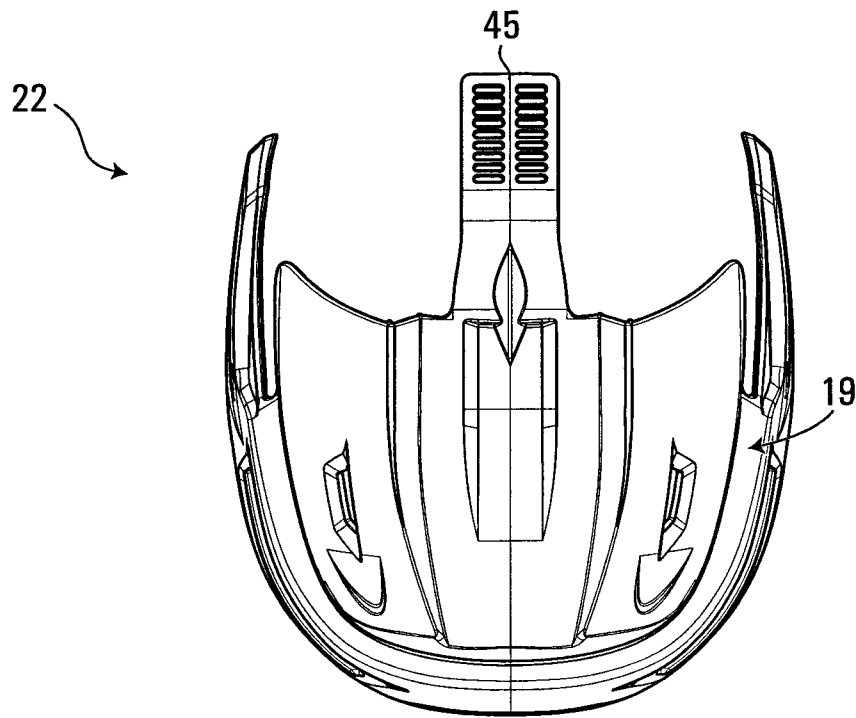
**FIG. 11**

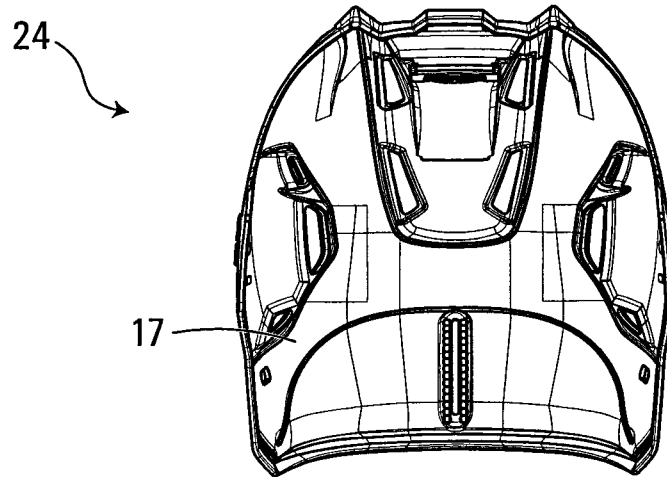
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**FIG. 12**

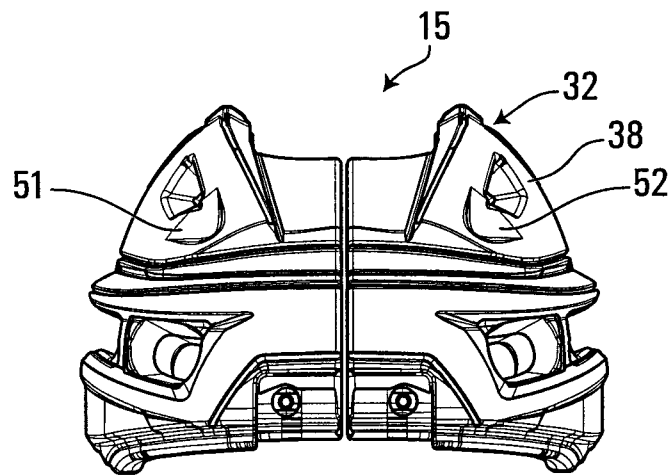
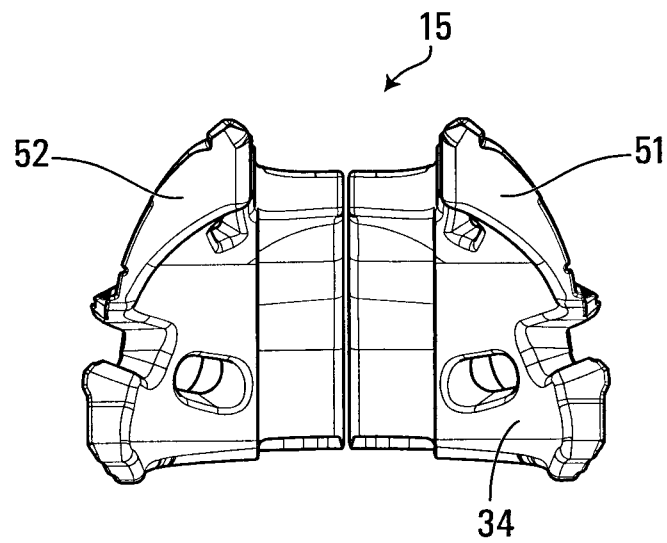
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**FIG. 13**

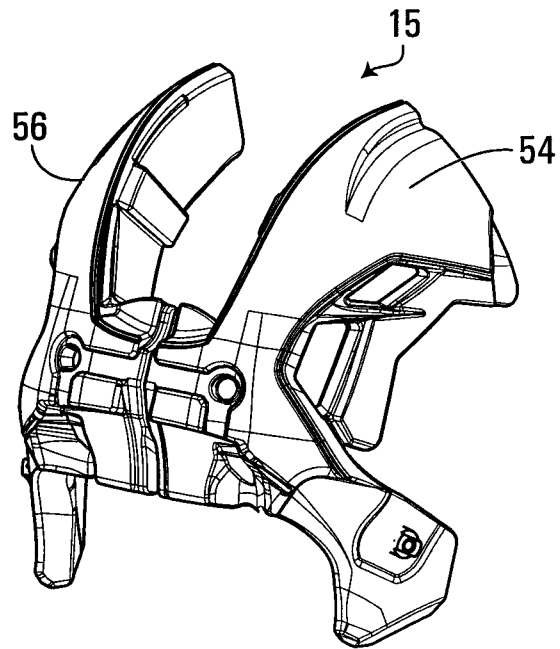
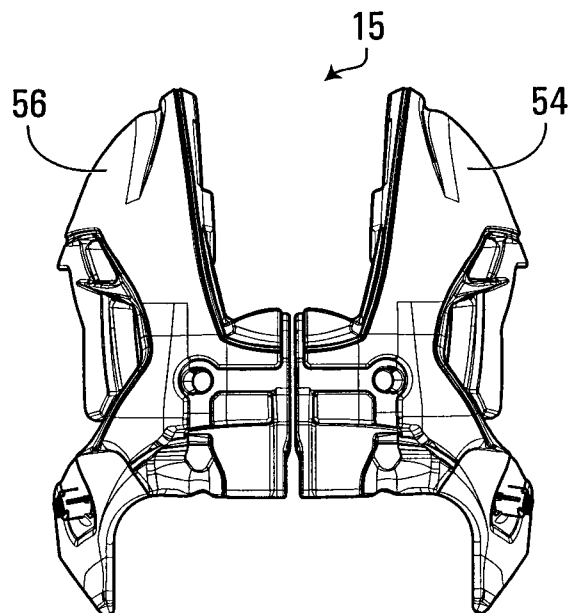
10/49**FIG. 14**

11/49**FIG. 15**

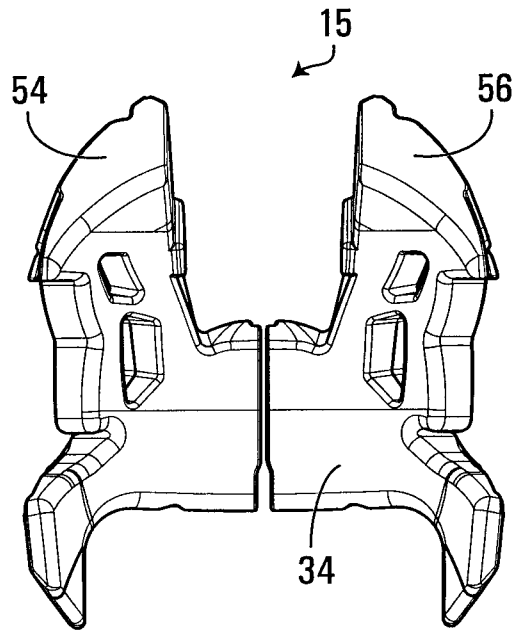
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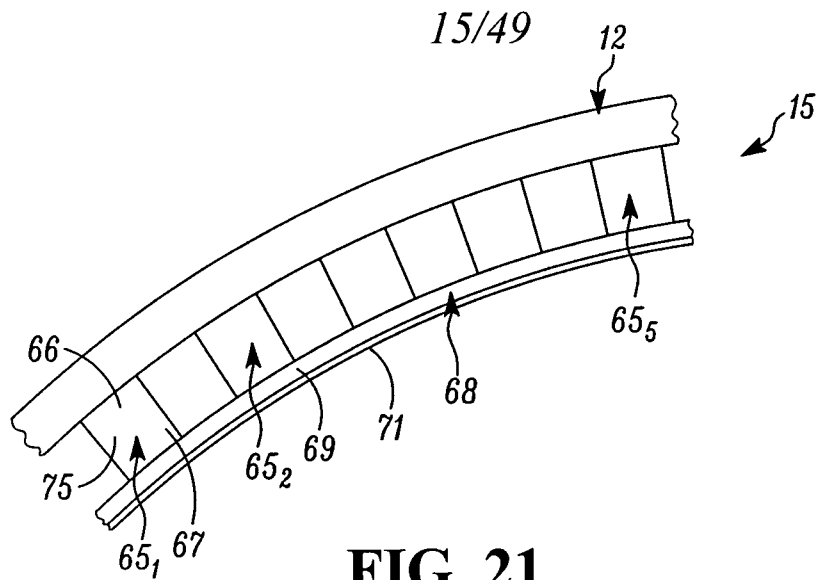
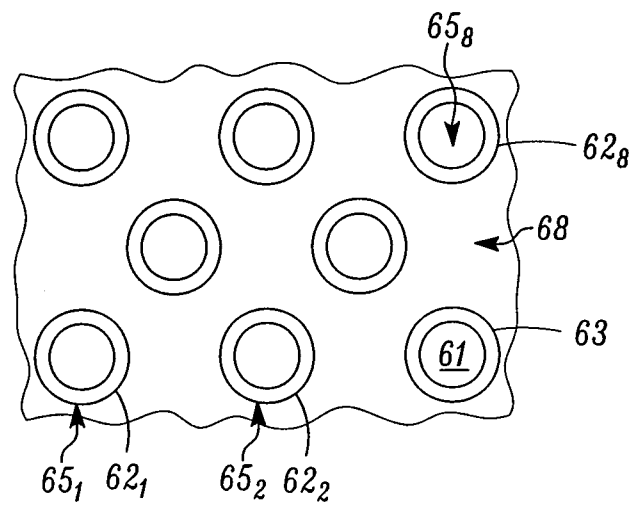
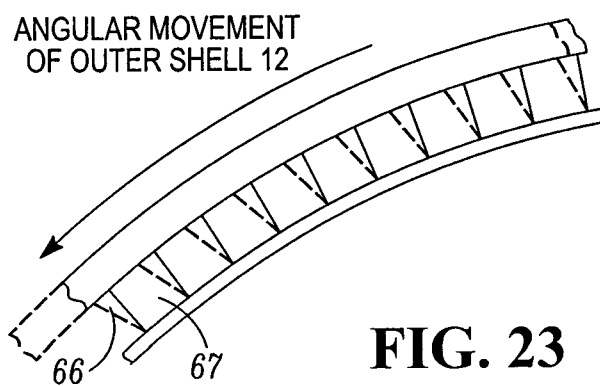
**FIG. 16****FIG. 17**

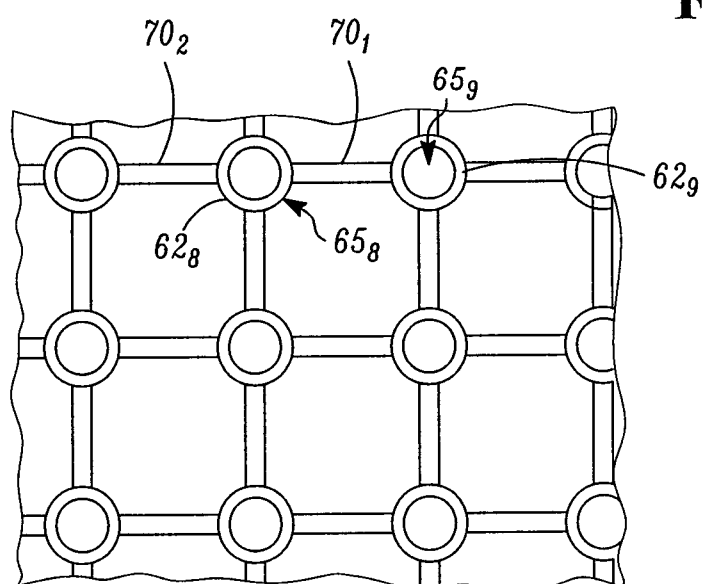
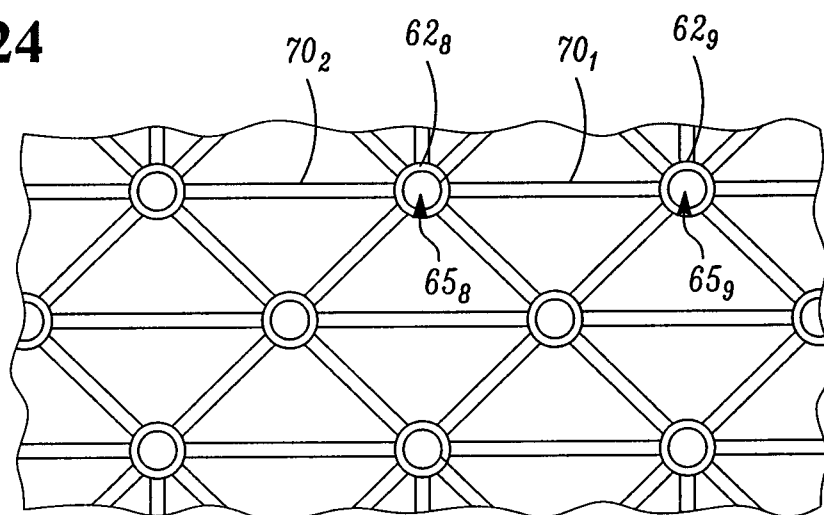
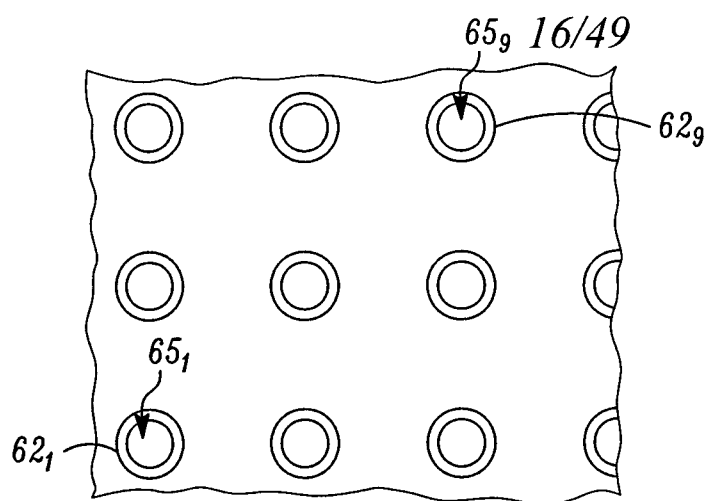
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**FIG. 18****FIG. 19**

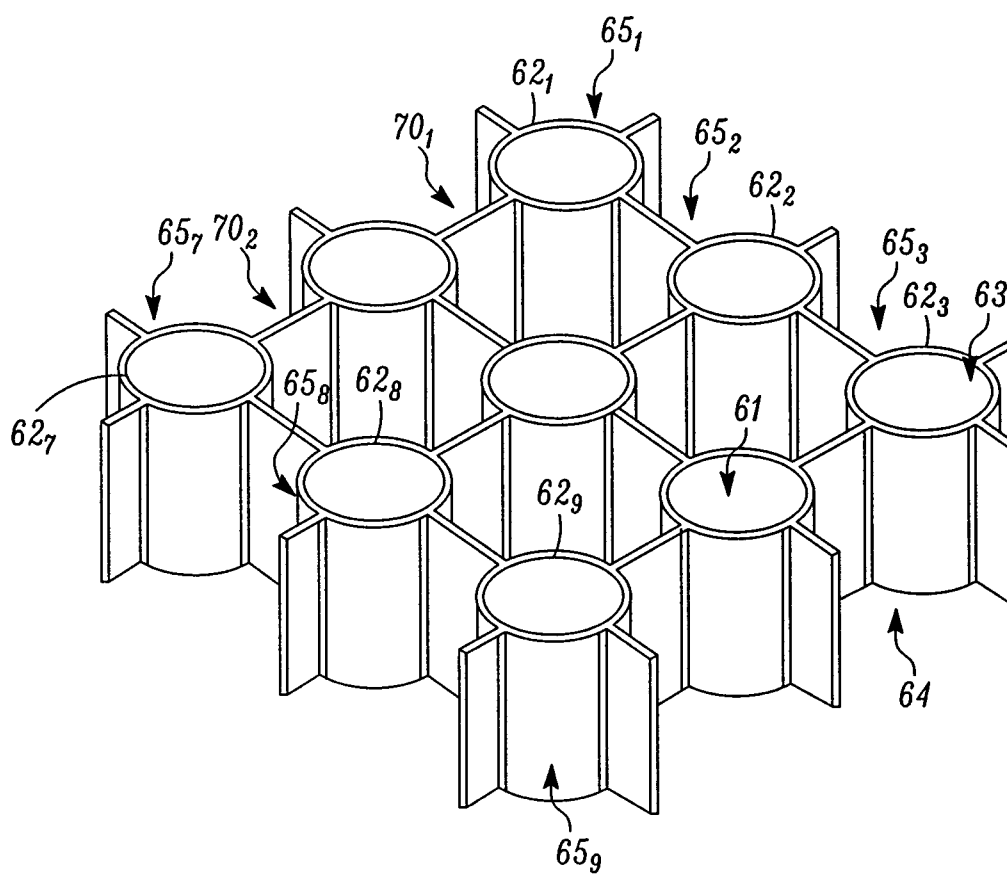
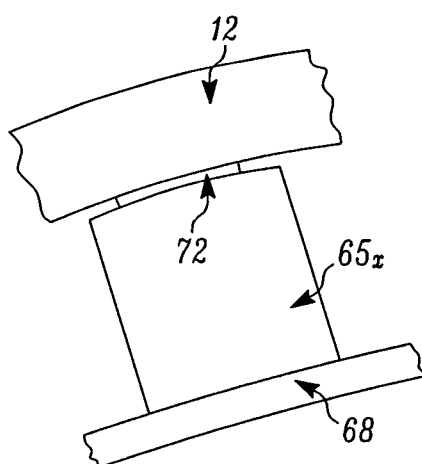
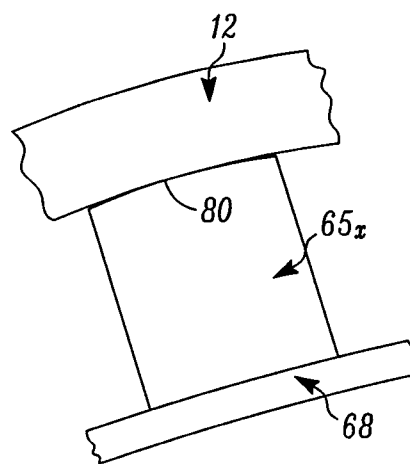
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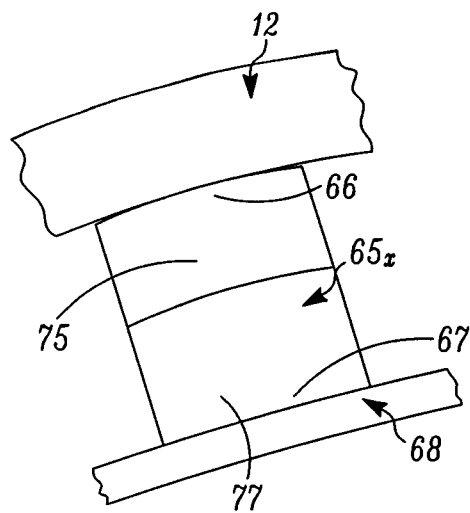
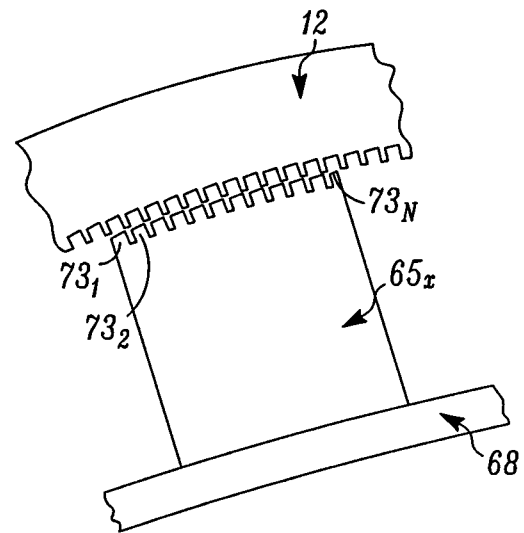
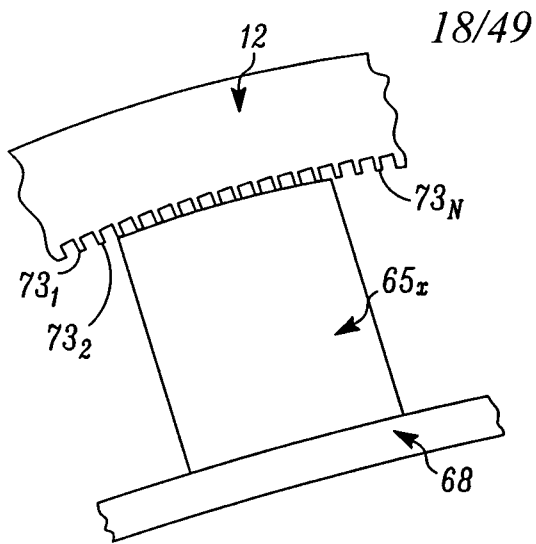
**FIG. 20**

**FIG. 21****FIG. 22****FIG. 23**

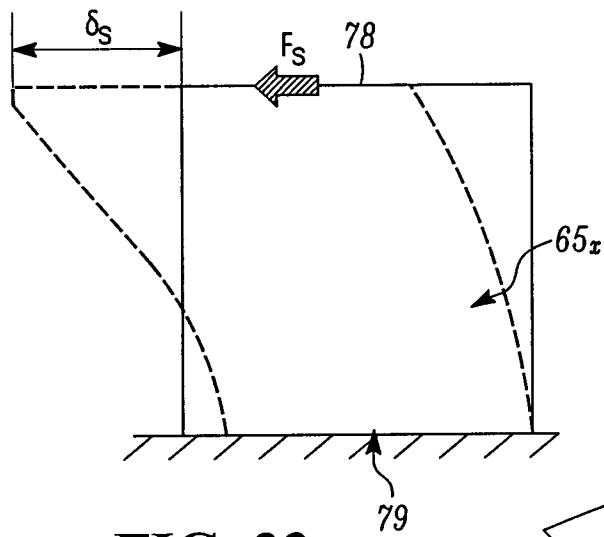
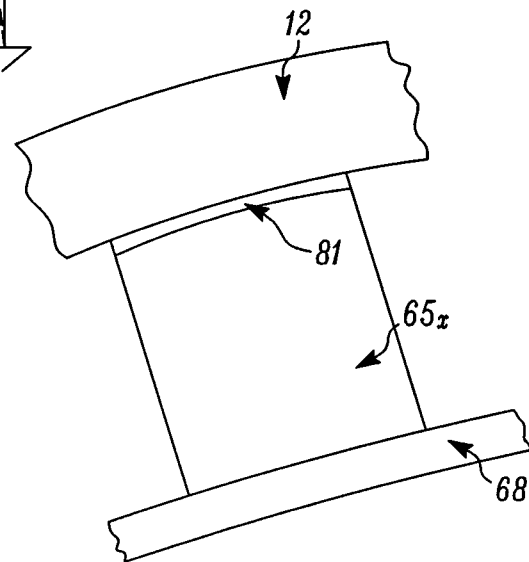
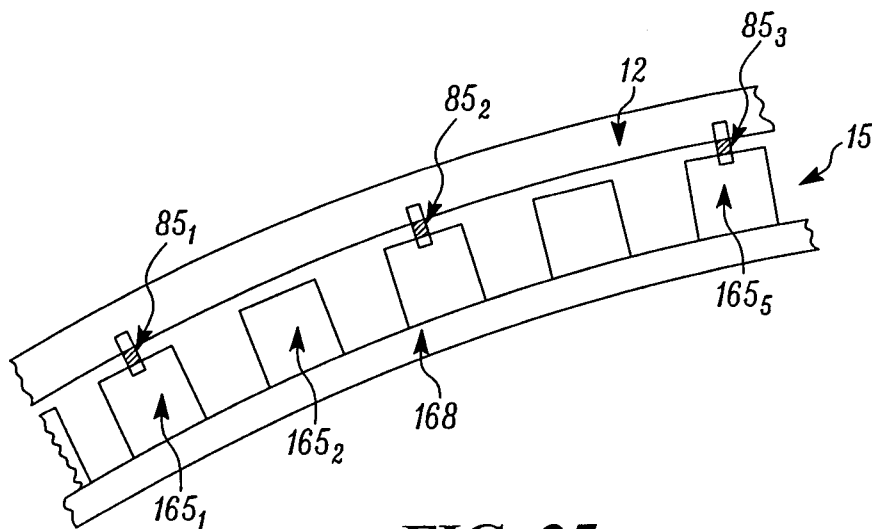


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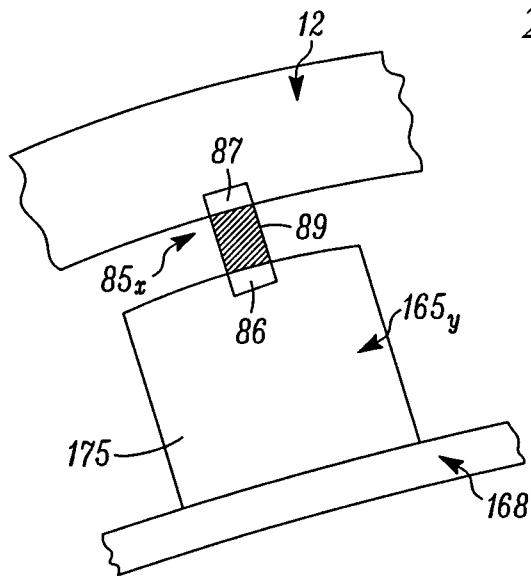
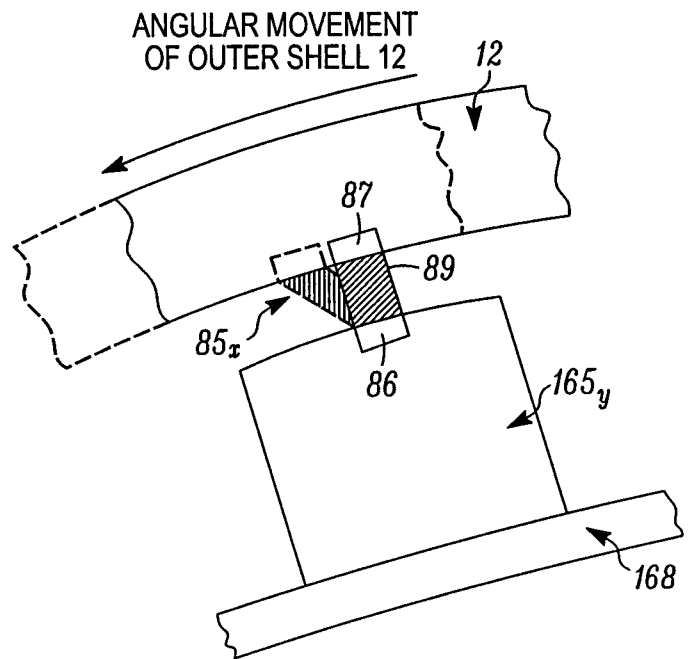
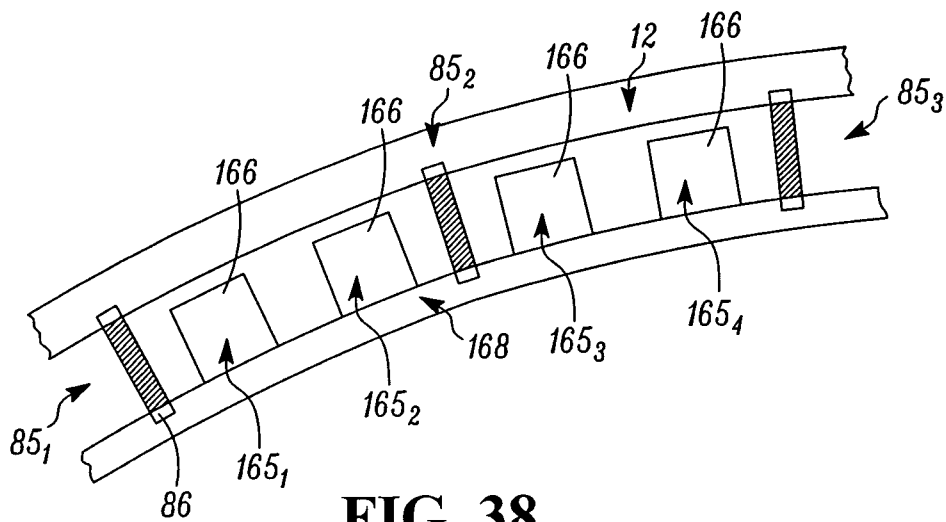
**FIG. 27****FIG. 28****FIG. 29**



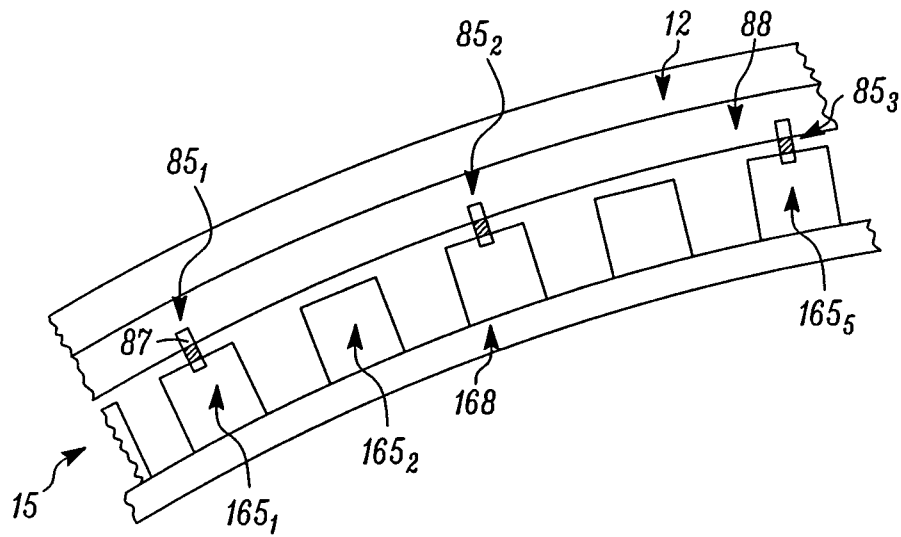
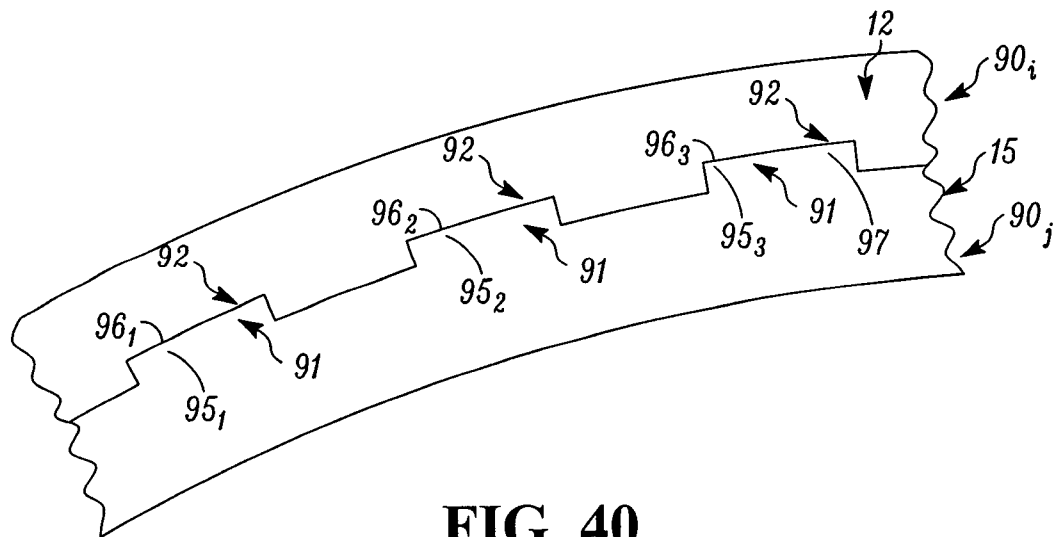
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**FIG. 33****FIG. 34****FIG. 35**

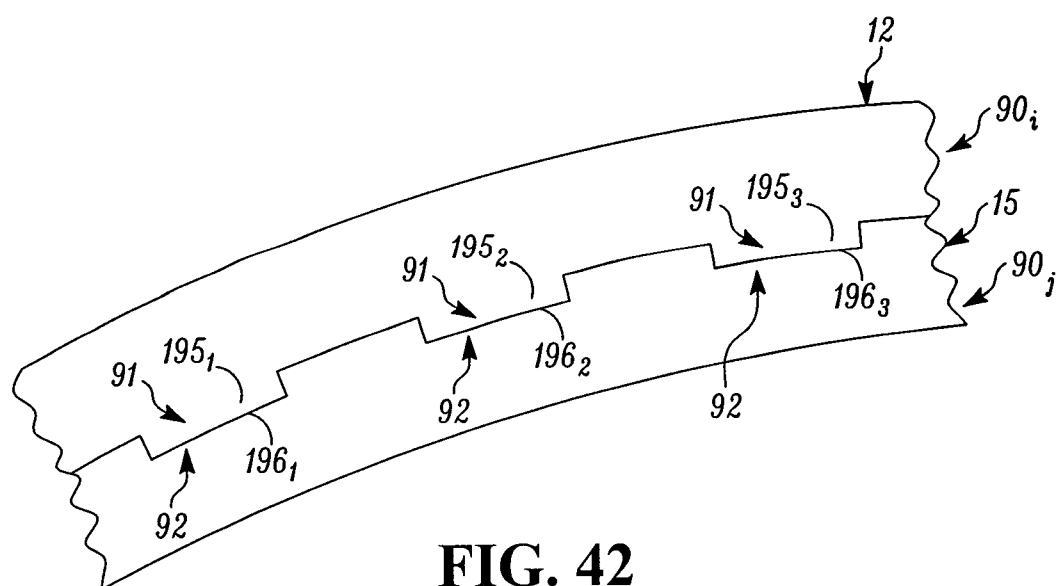
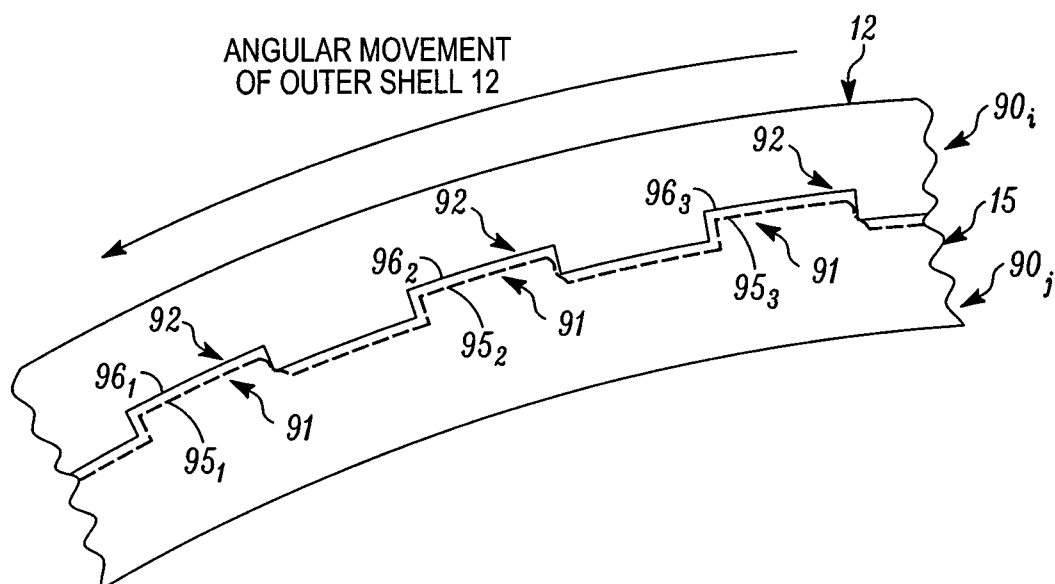
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**FIG. 36****FIG. 37****FIG. 38**

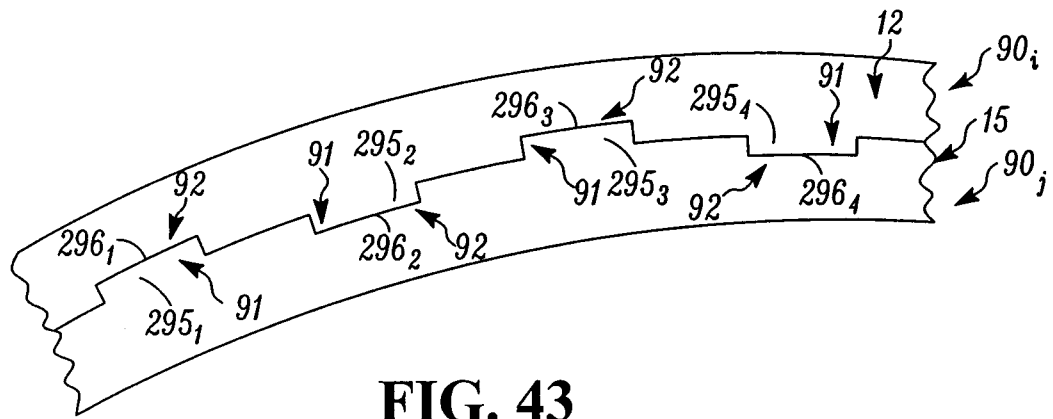
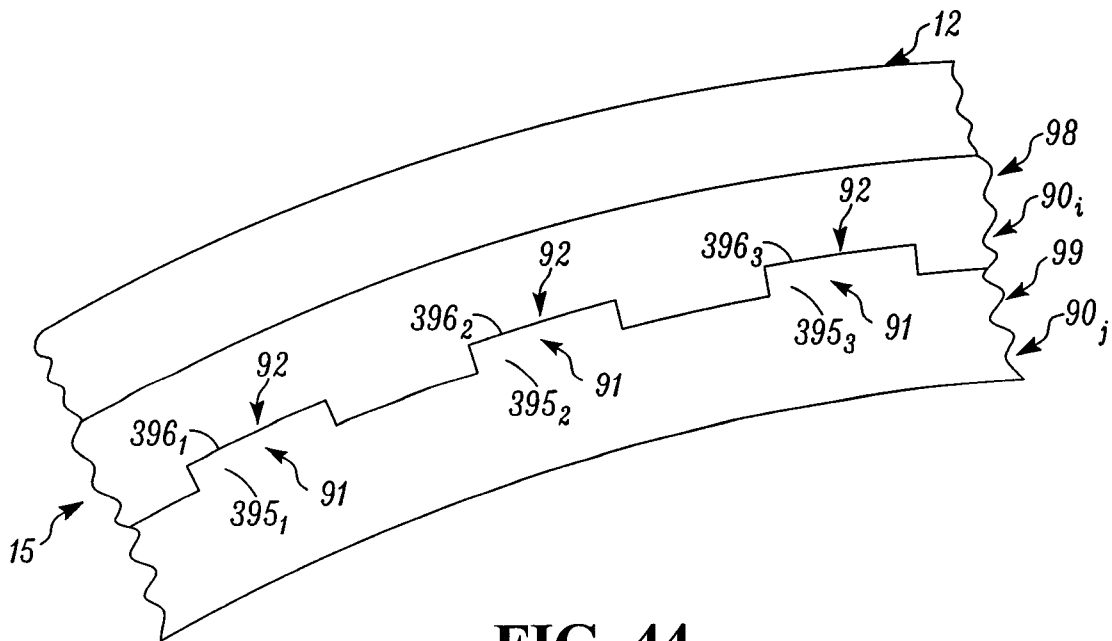
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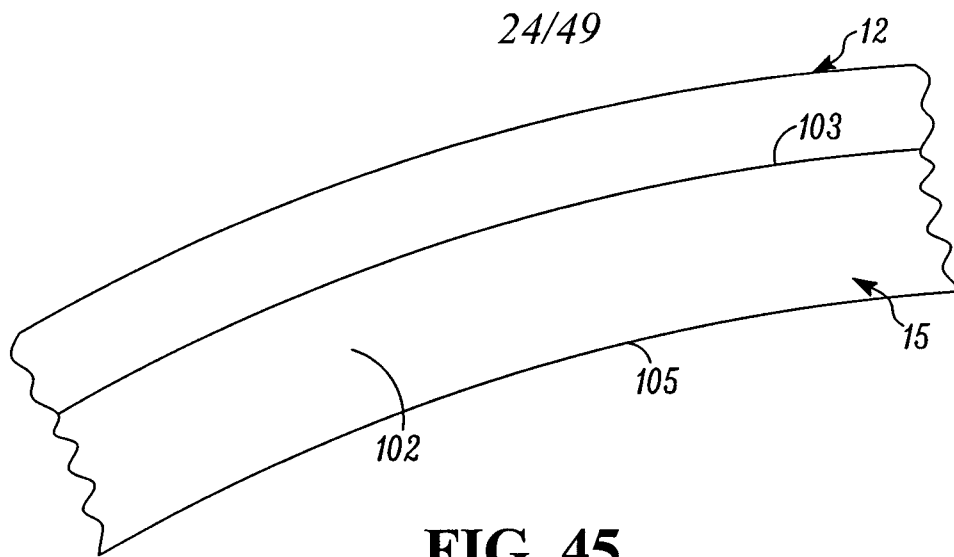
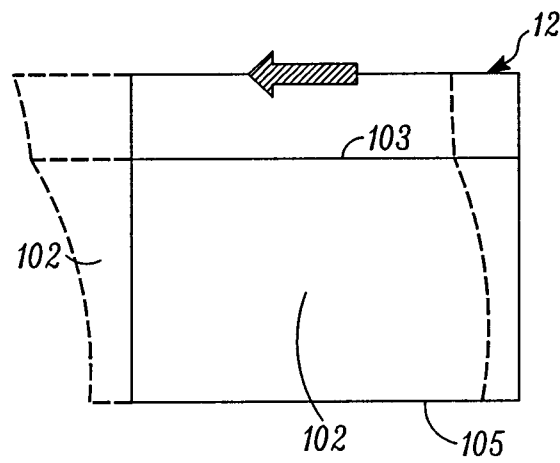
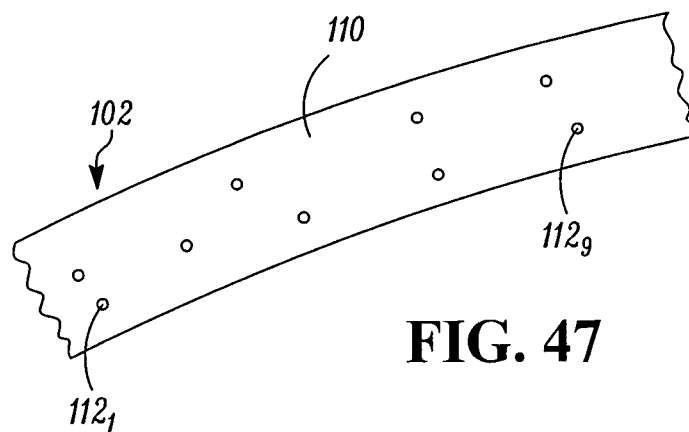
**FIG. 39****FIG. 40**

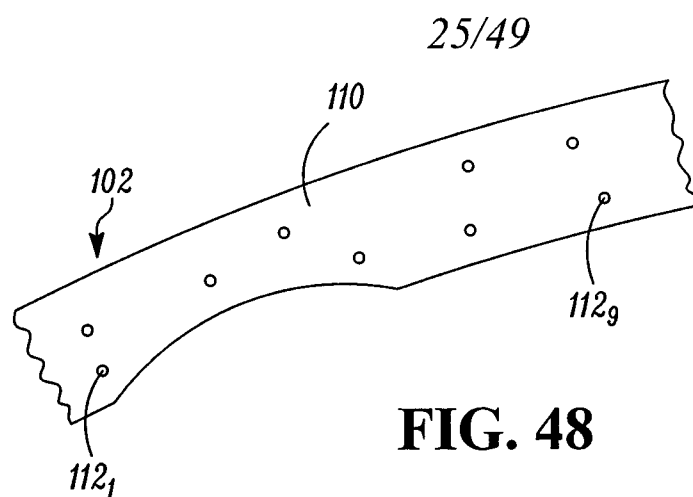
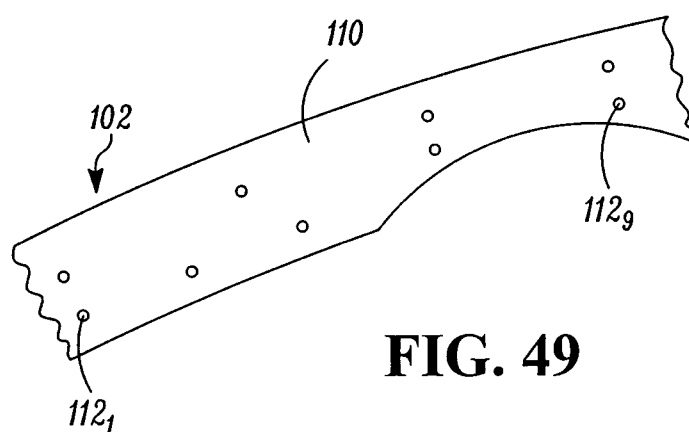
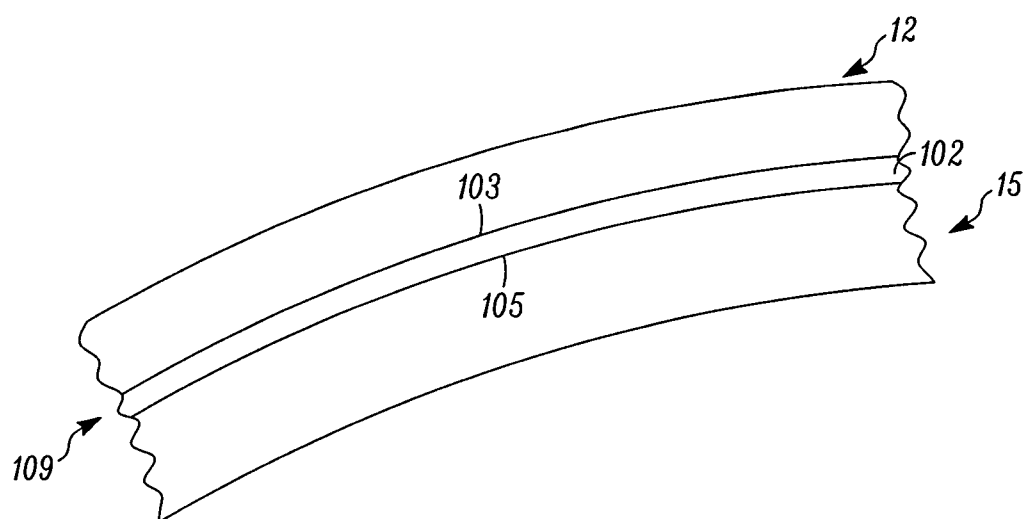
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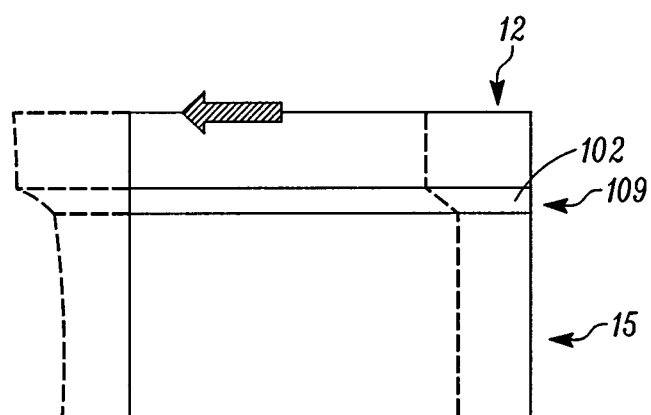
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**FIG. 43****FIG. 44**

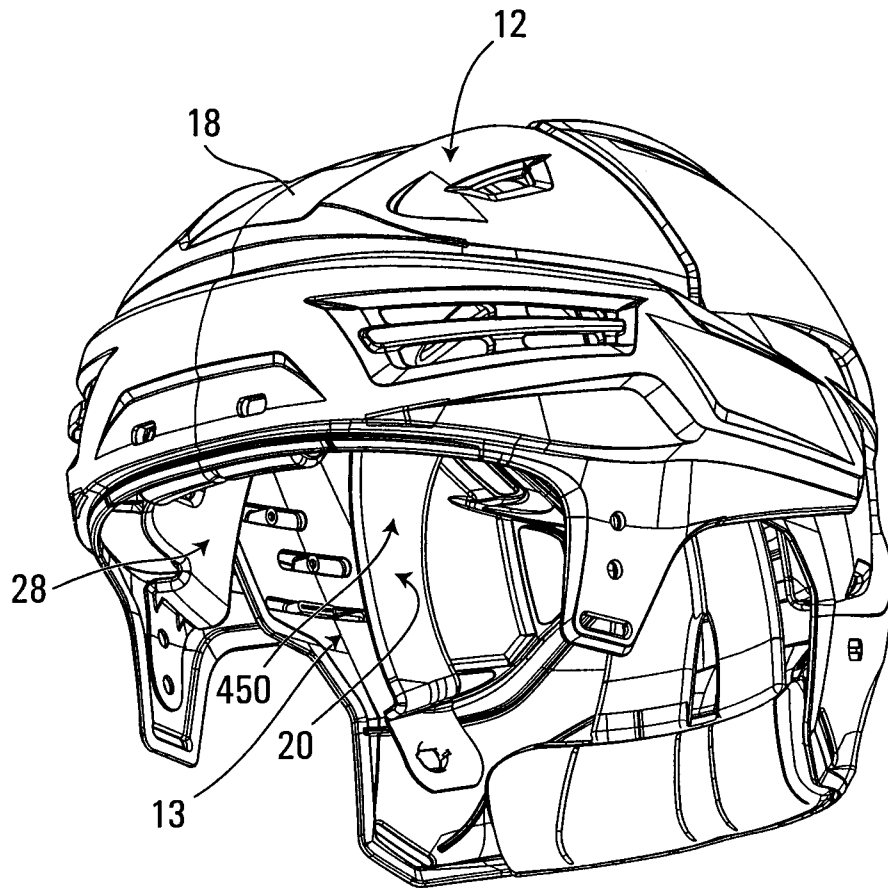
**FIG. 45****FIG. 46****FIG. 47**

**FIG. 48****FIG. 49****FIG. 50**

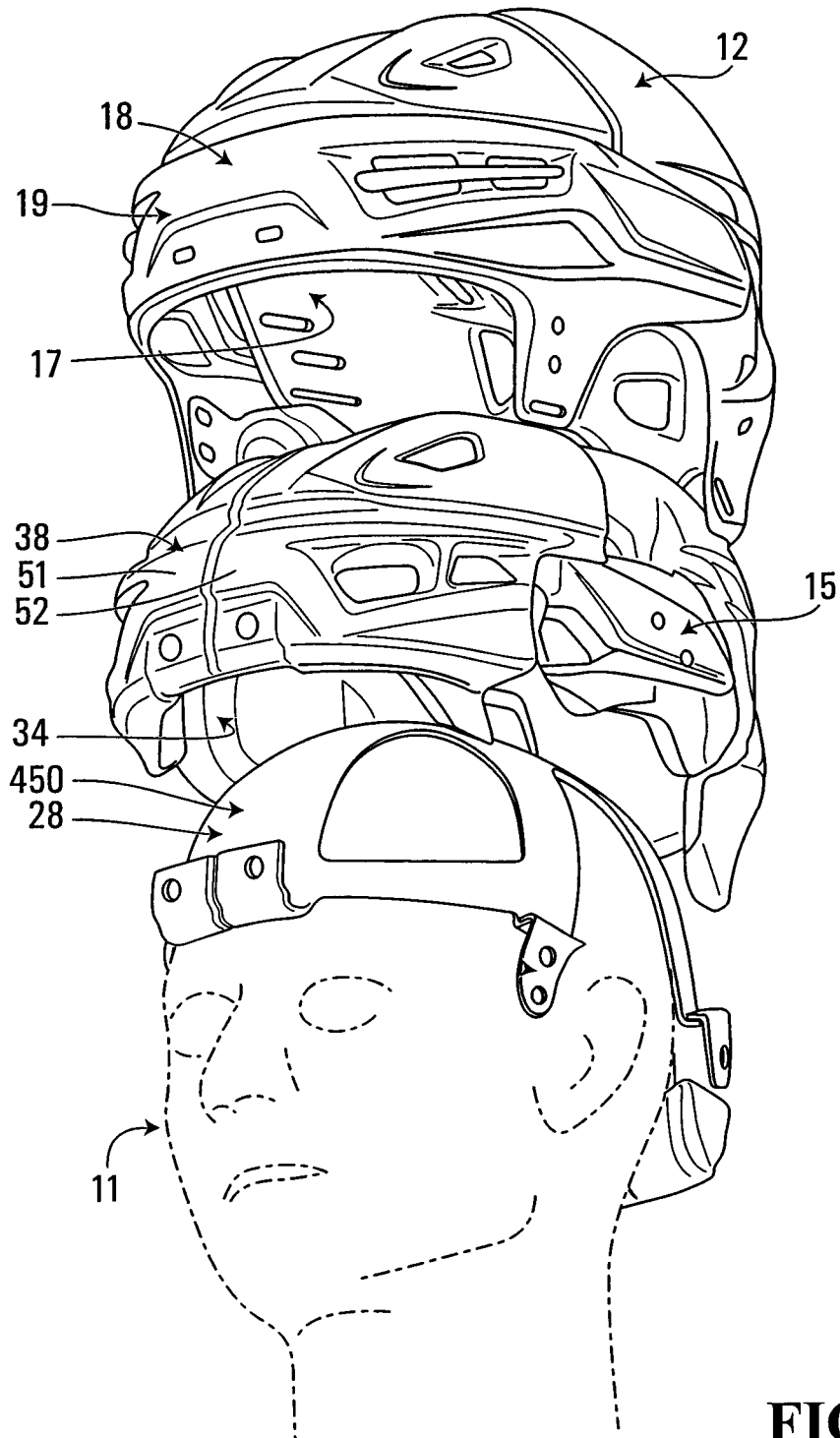
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**FIG. 51**

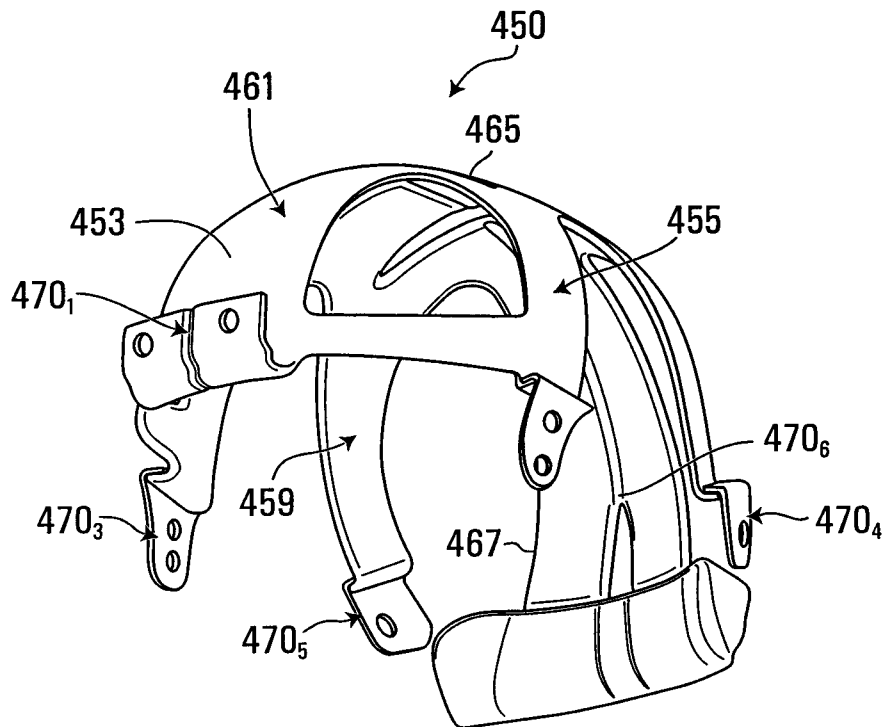
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**FIG. 52**

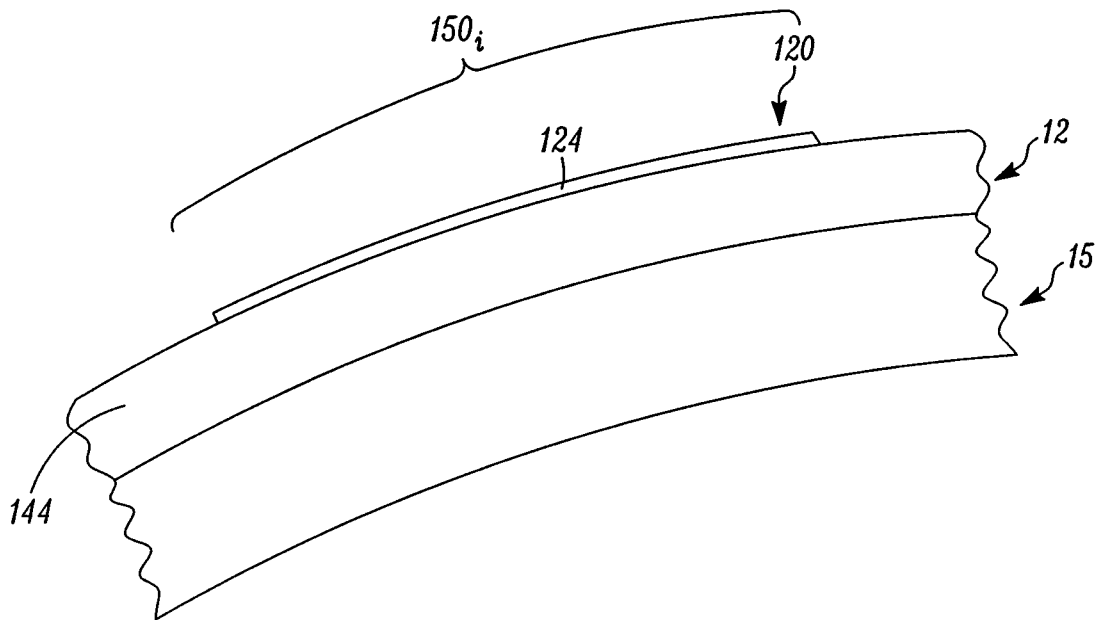
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**FIG. 53**

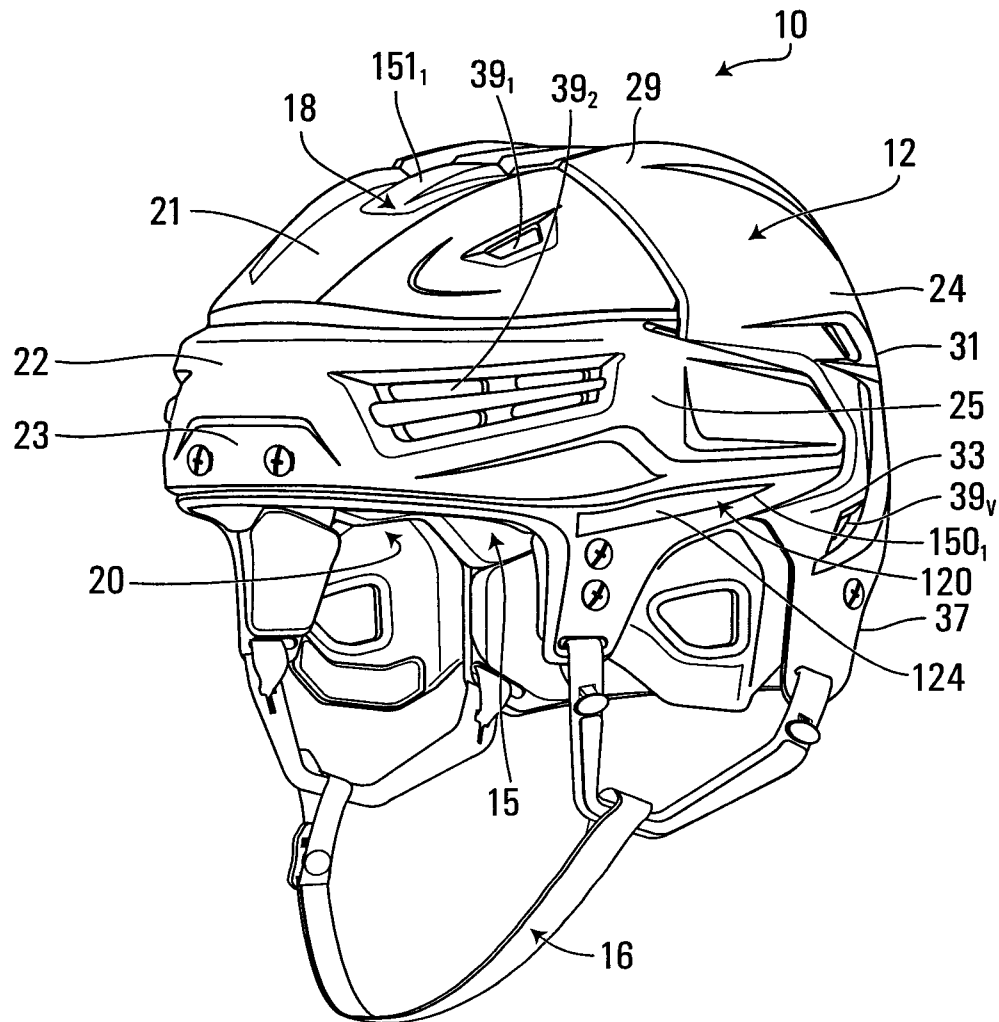
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**FIG. 54**

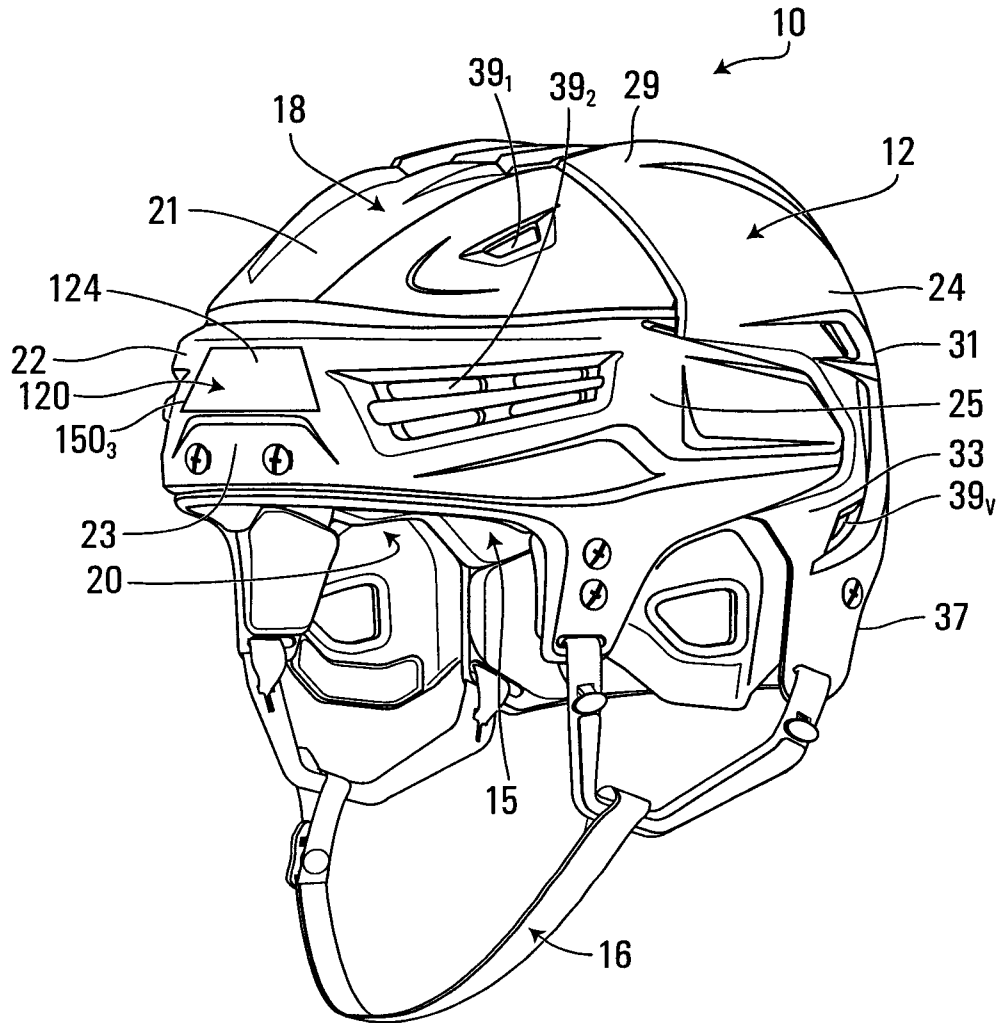
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*FIG. 55*

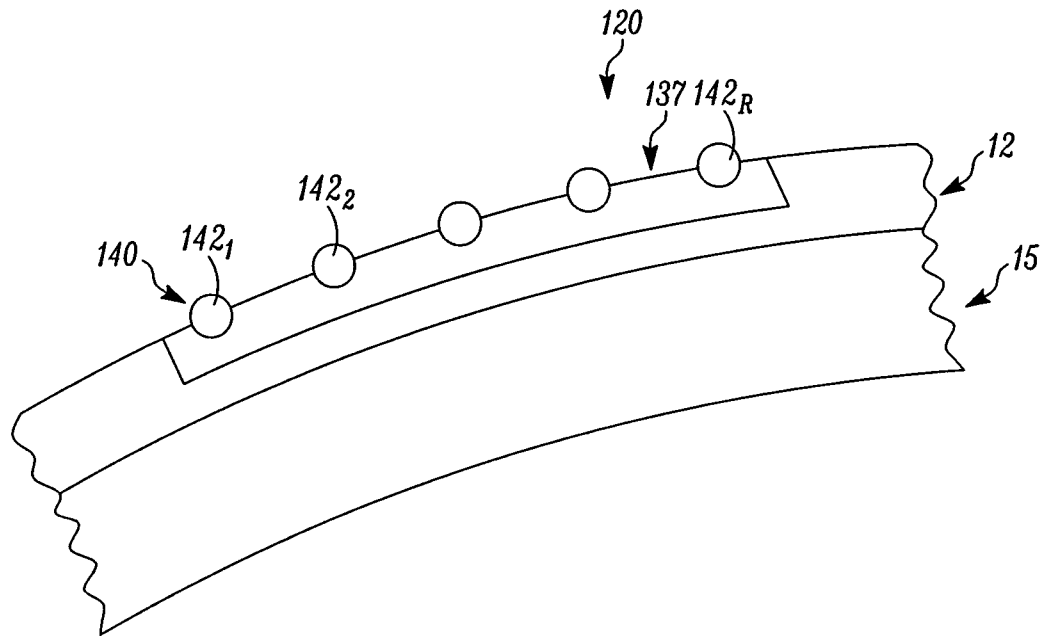
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**FIG. 56**

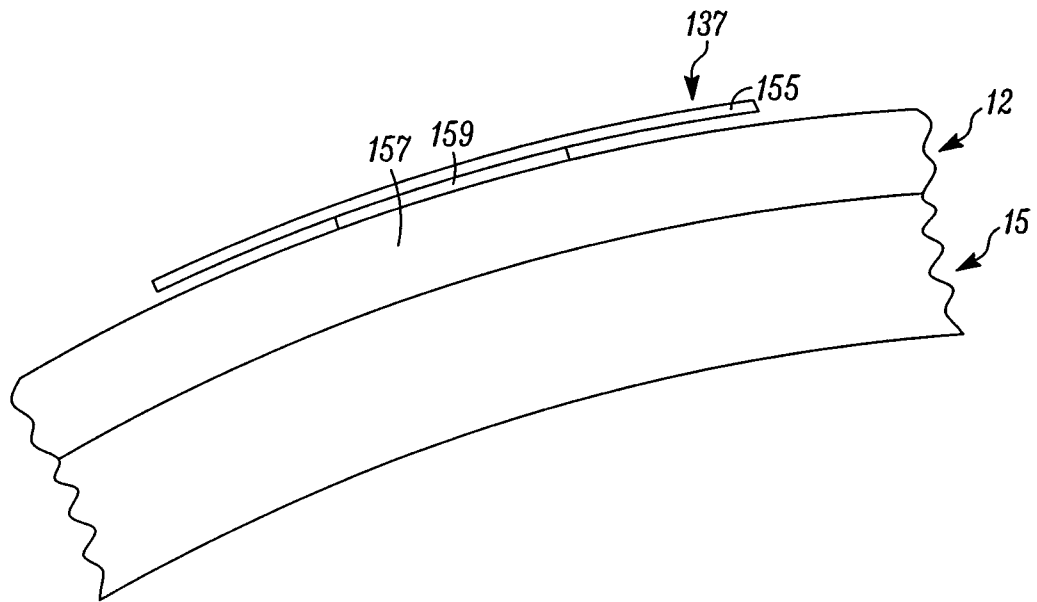
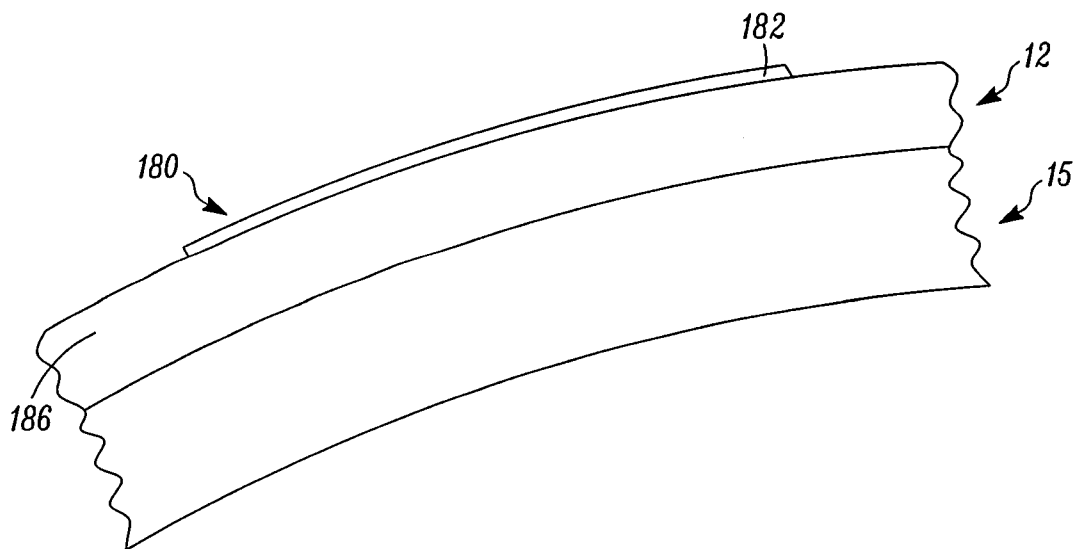
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**FIG. 57**

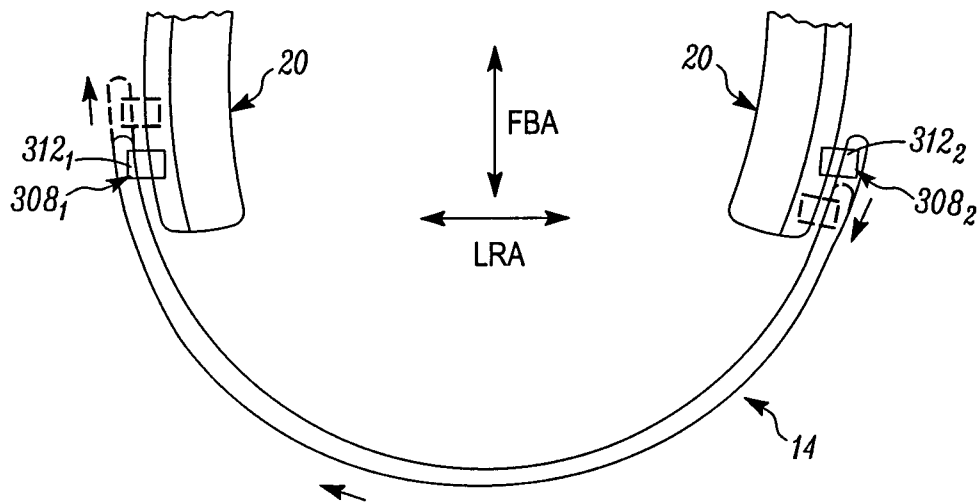
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*FIG. 58*

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*FIG. 59**FIG. 60*

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*FIG. 61*

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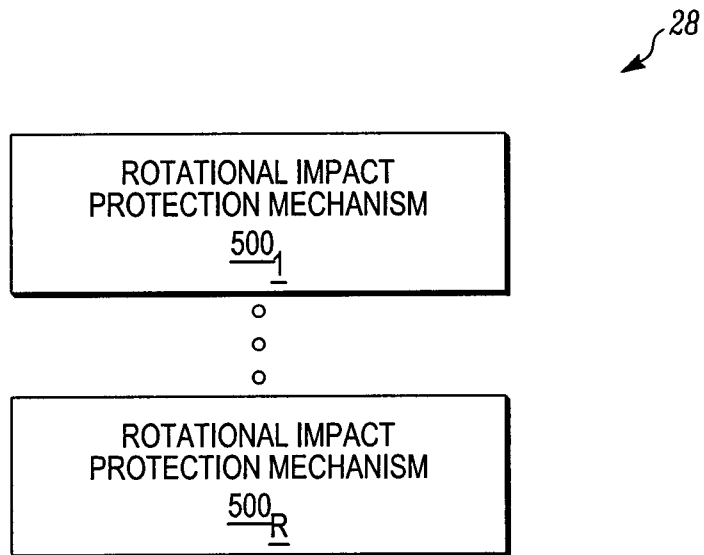


FIG. 62

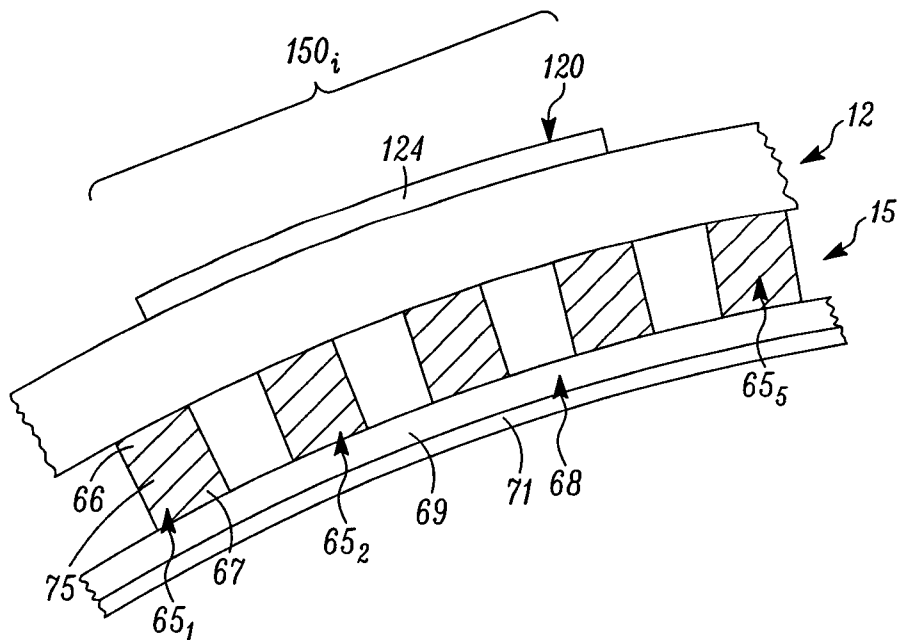


FIG. 63

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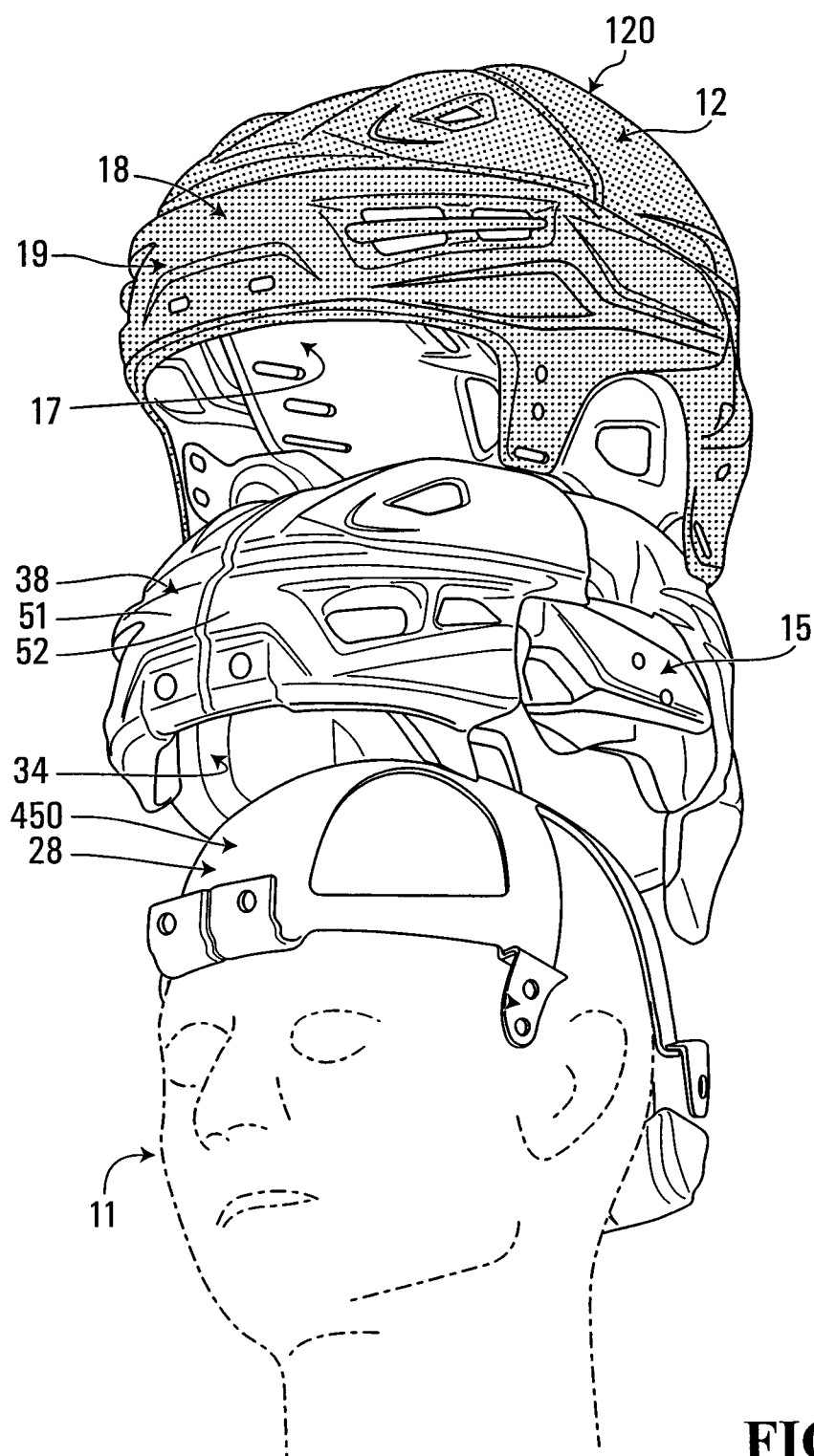
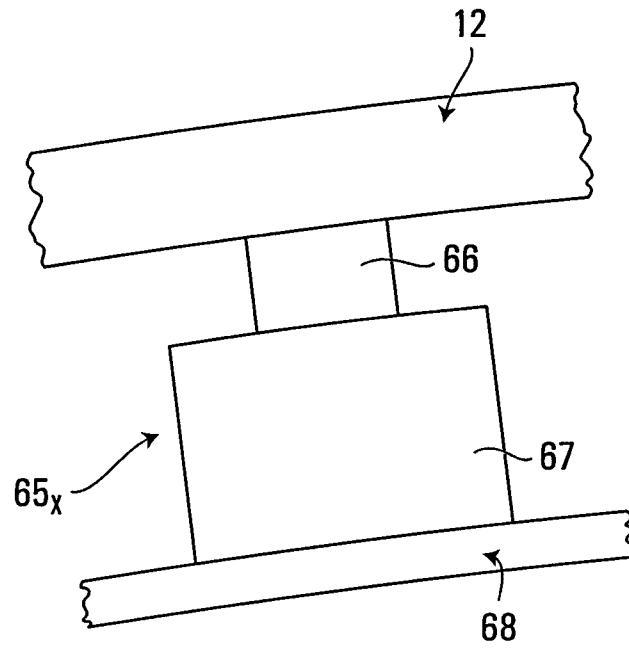
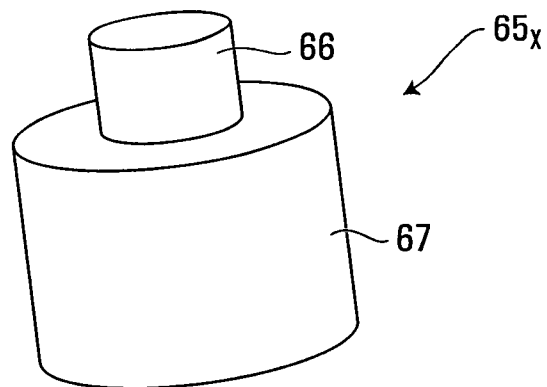
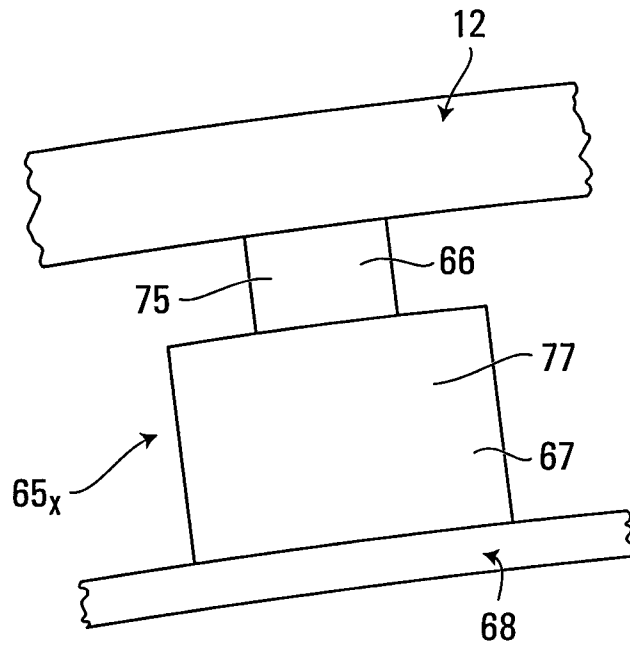


FIG. 64

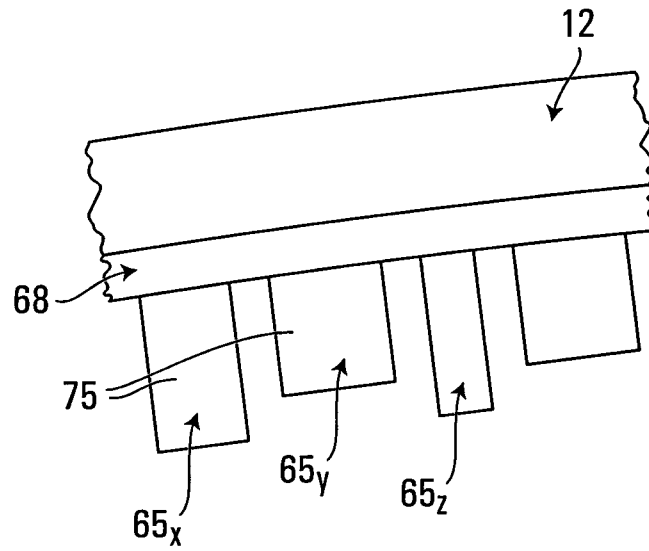
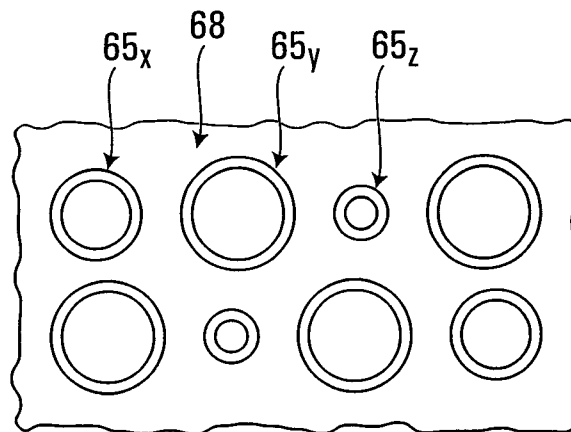
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**FIG. 65****FIG. 66**

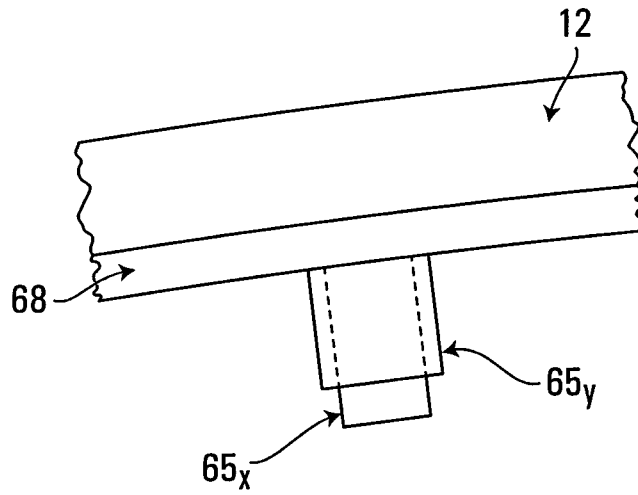
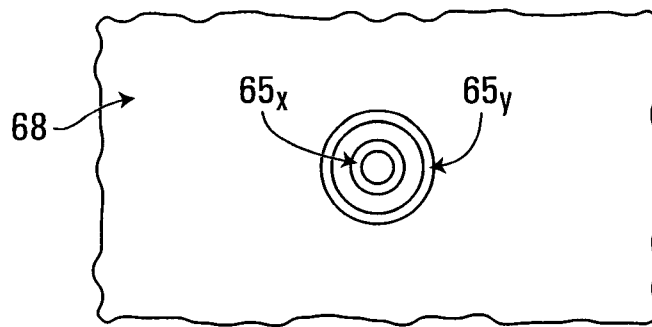
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**FIG. 67**

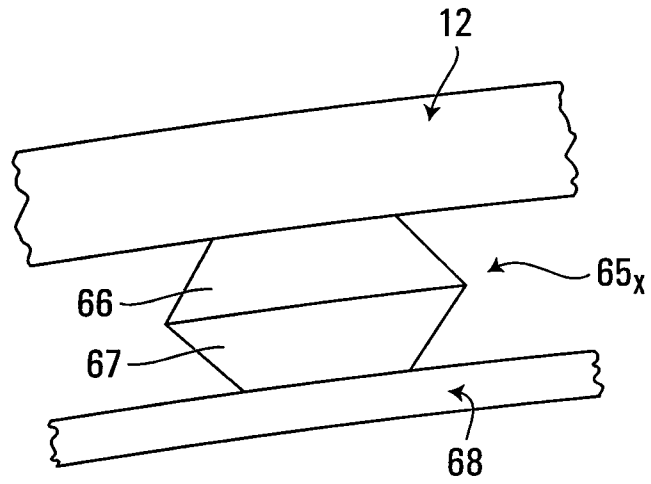
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**FIG. 68****FIG. 69**

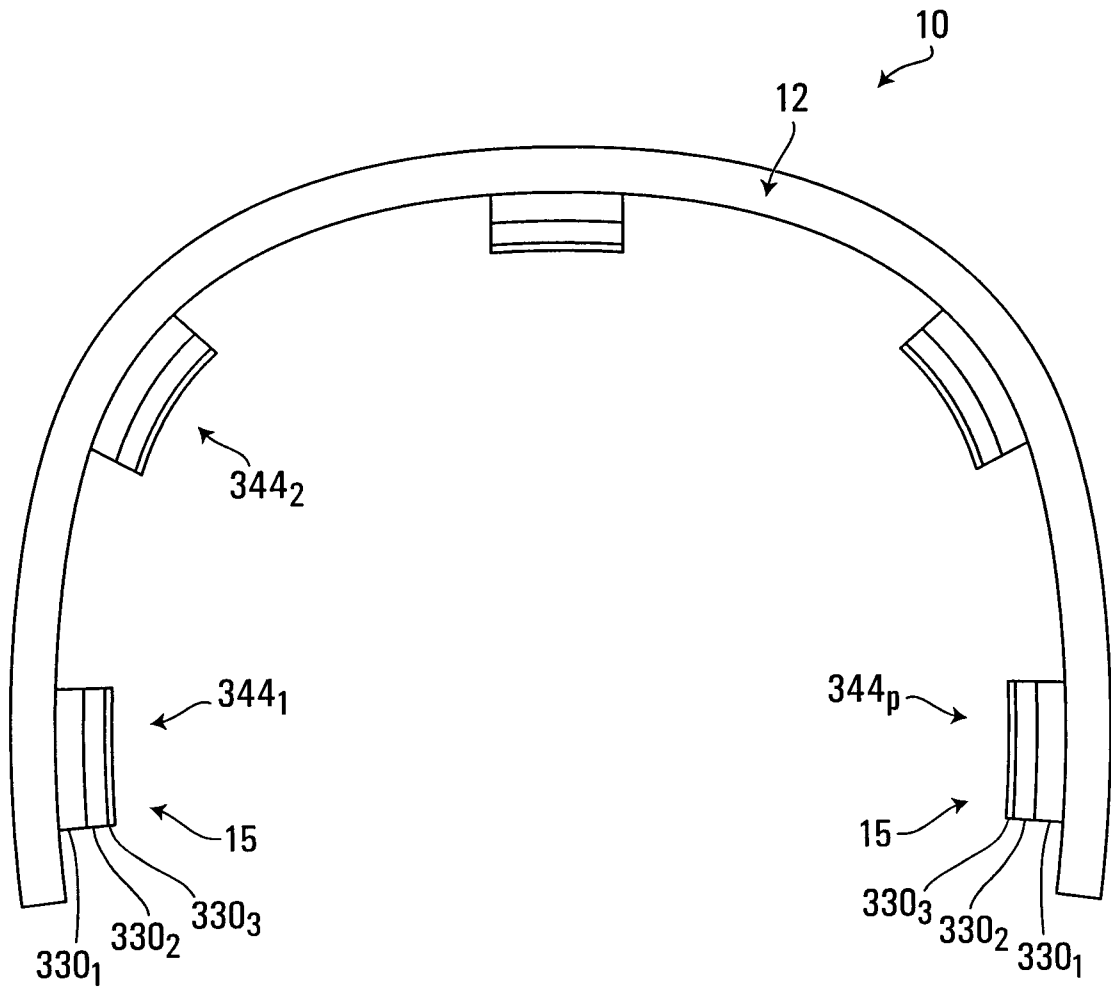
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**FIG. 70****FIG. 71**

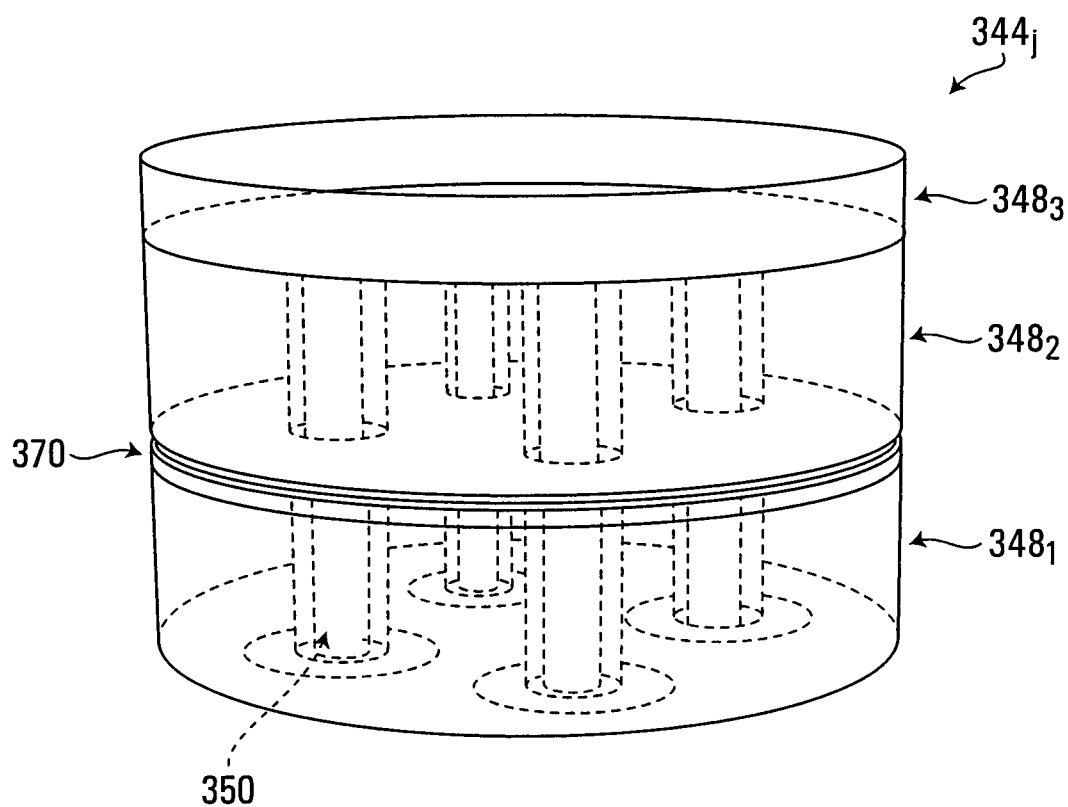
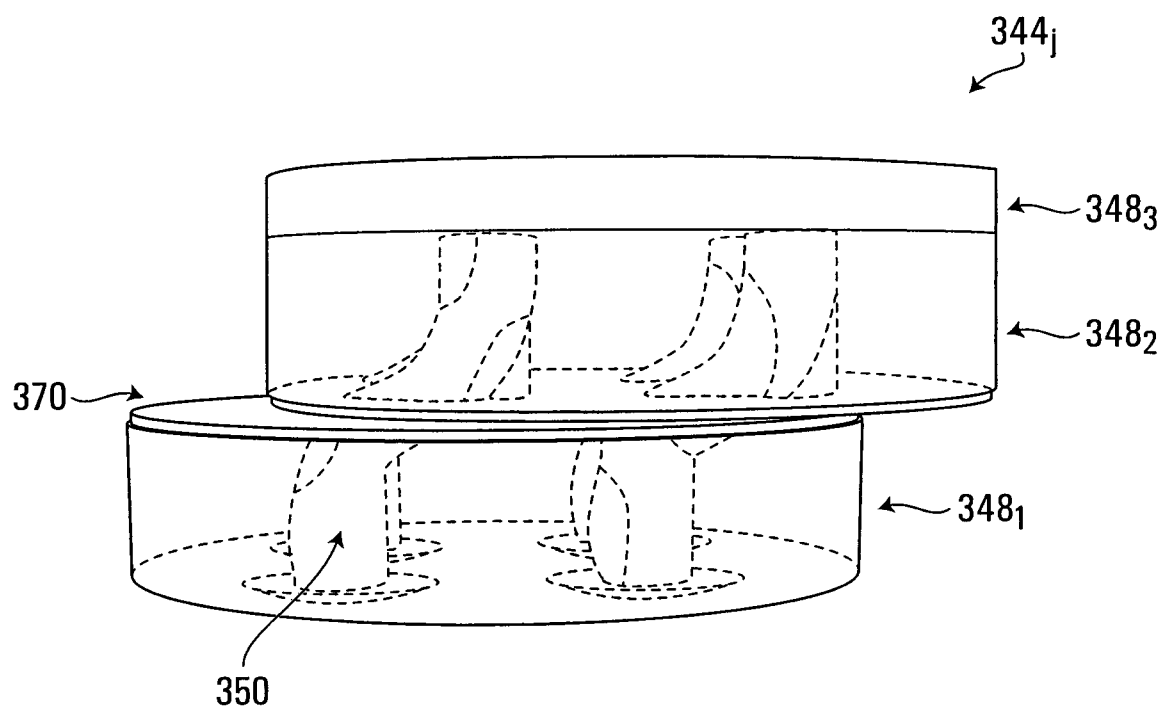
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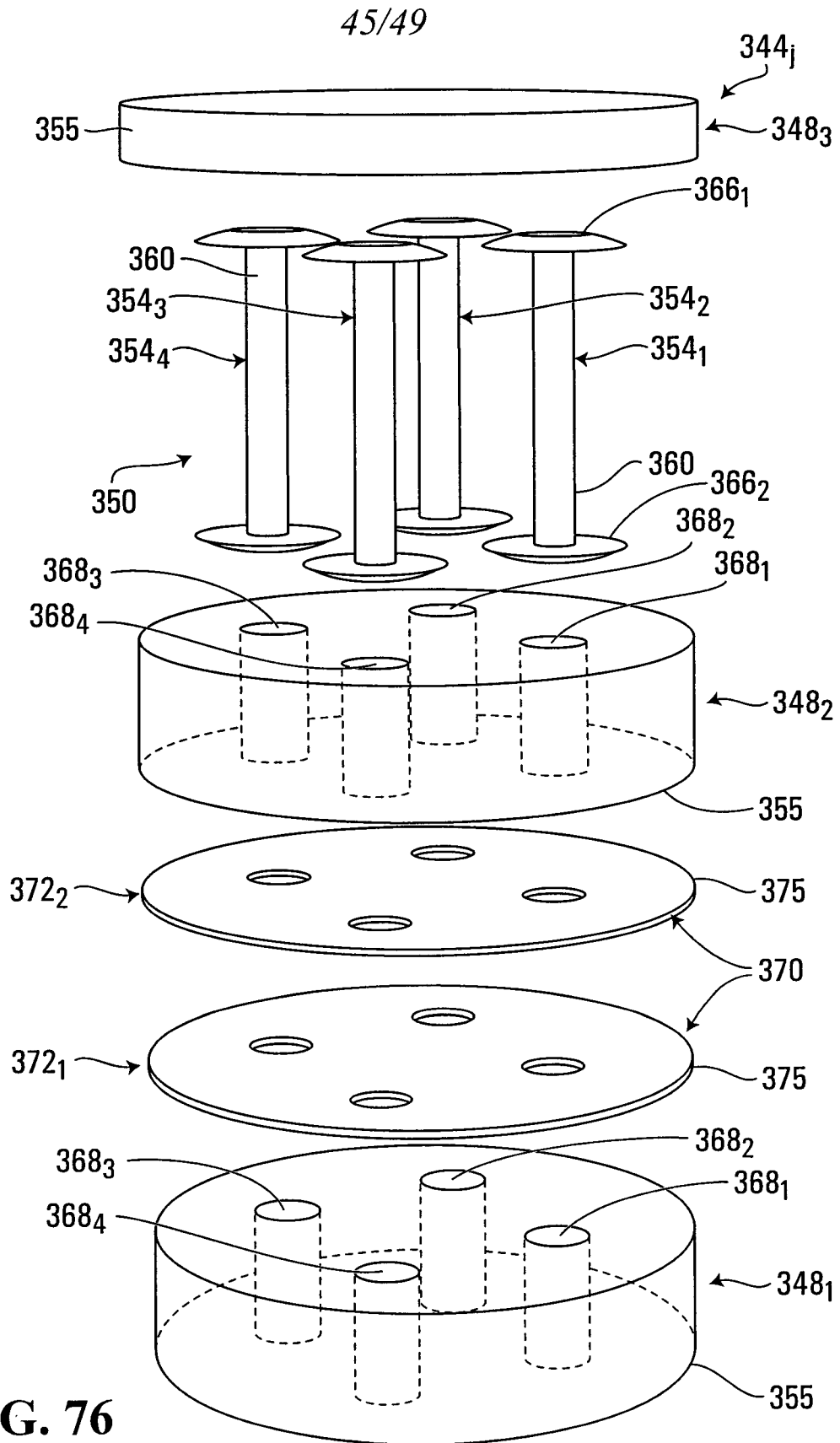
**FIG. 72**

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**FIG. 73**

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**FIG. 74****FIG. 75**

**FIG. 76**

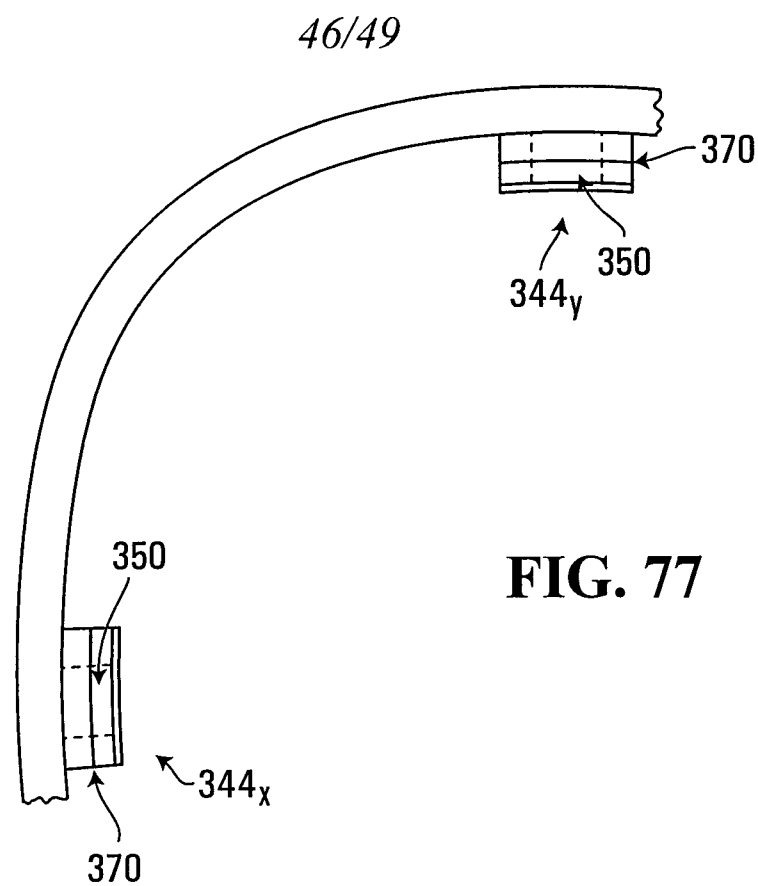


FIG. 77

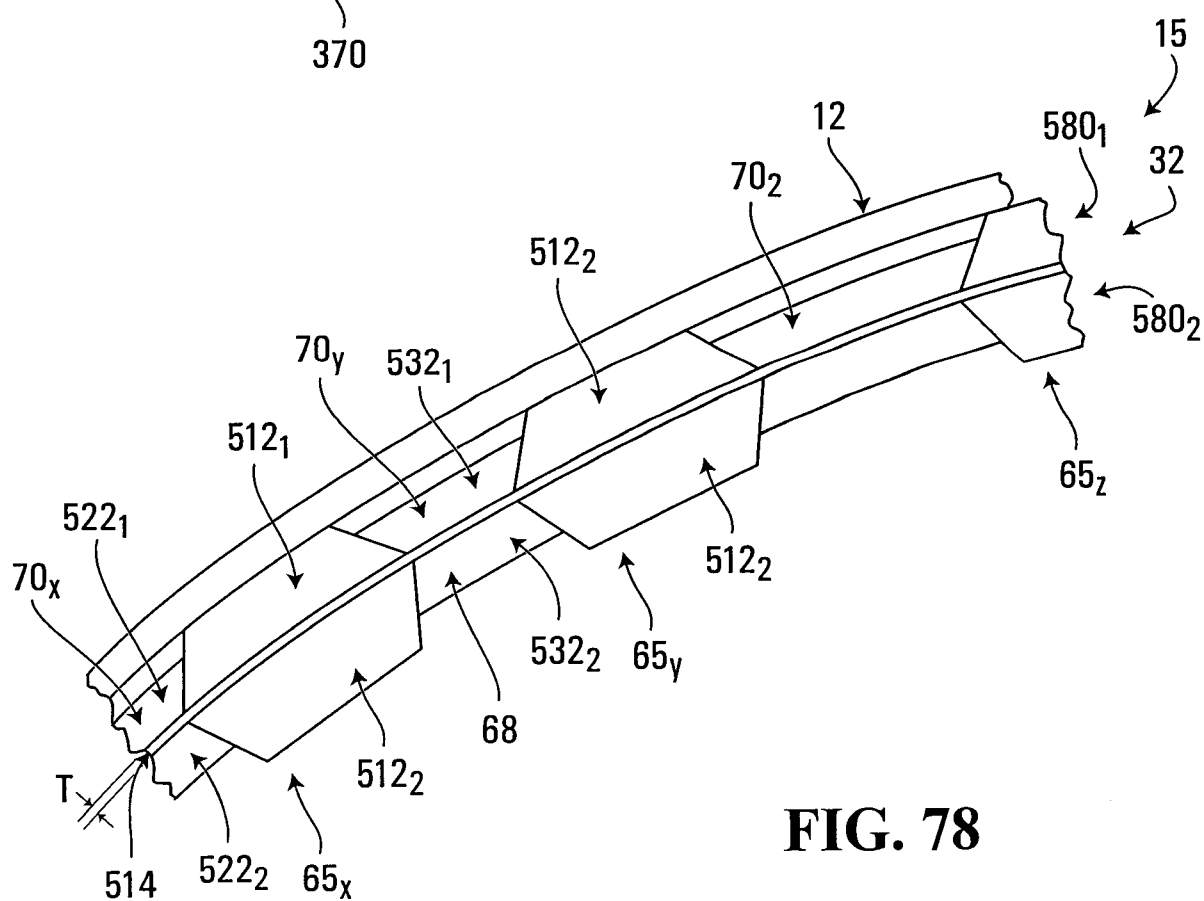
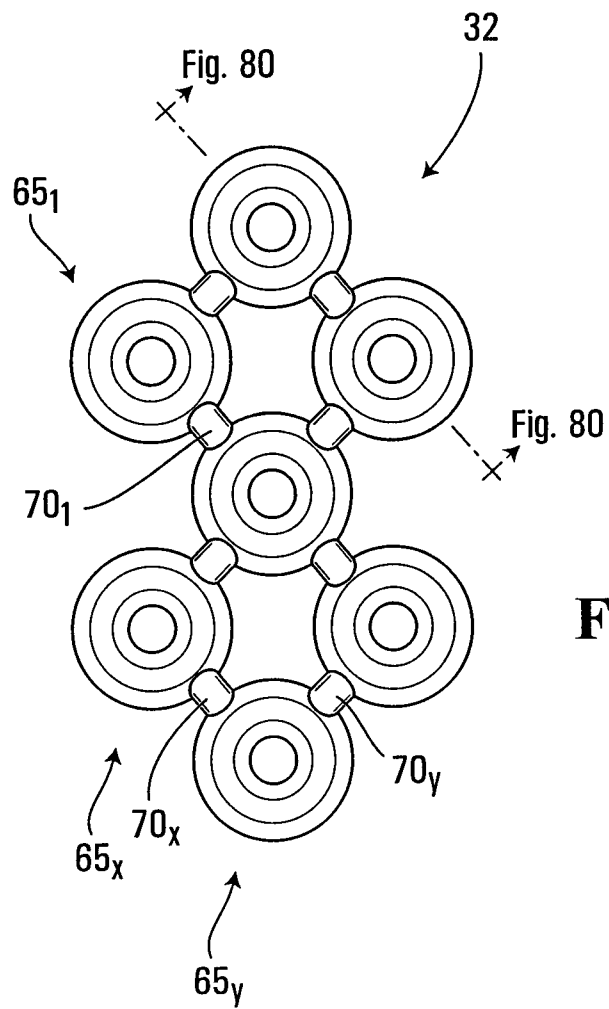
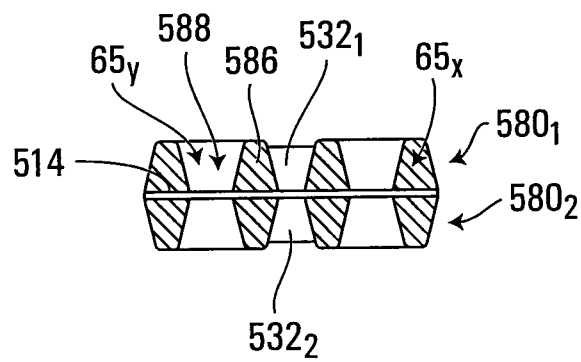
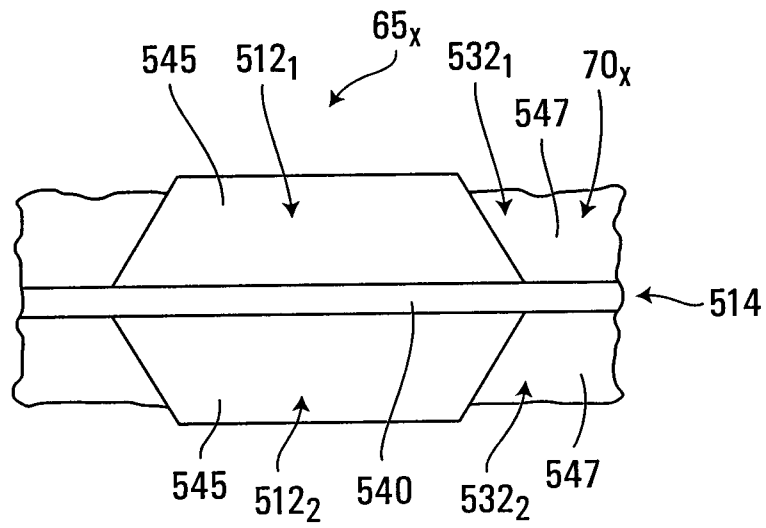
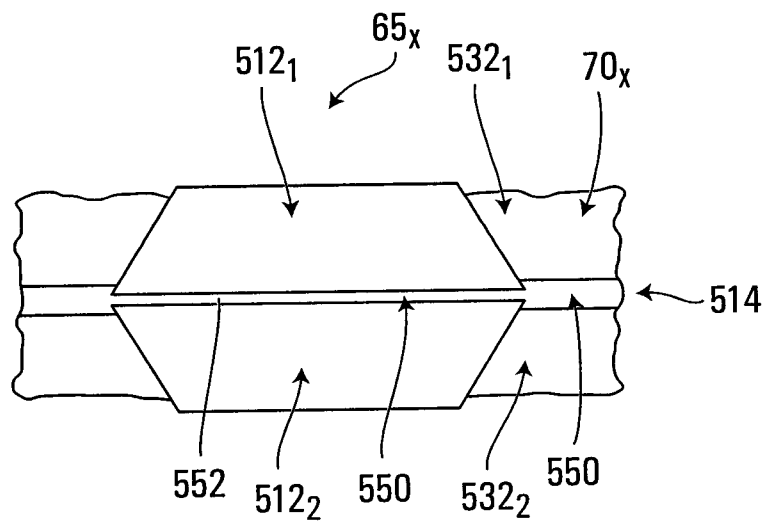


FIG. 78

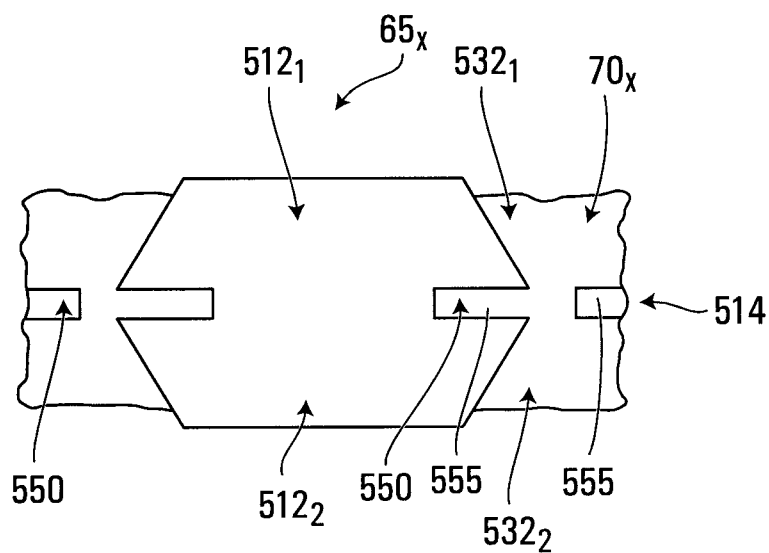
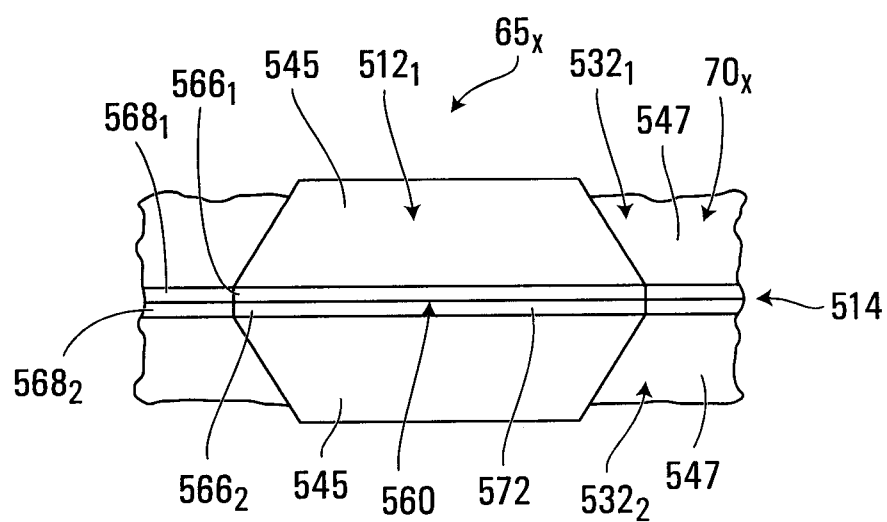
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**FIG. 79****FIG. 80**

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**FIG. 81****FIG. 82**

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**FIG. 83****FIG. 84**

