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(54) **OUTER PADDING ASSEMBLY FOR BIOMECHANICS AWARE HEADGEAR**

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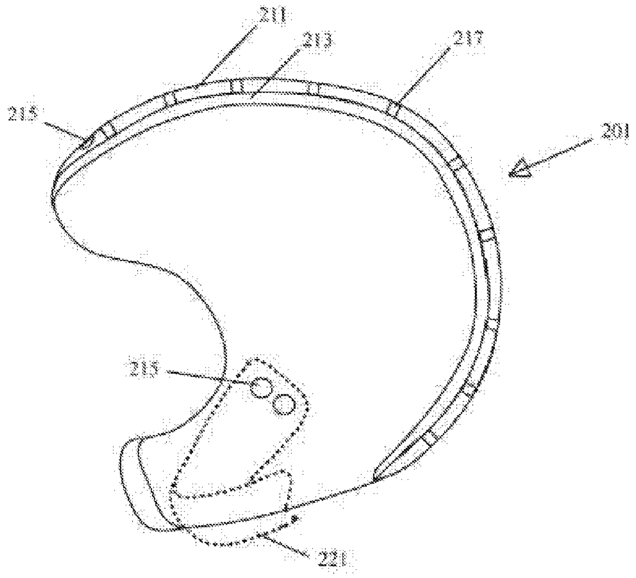
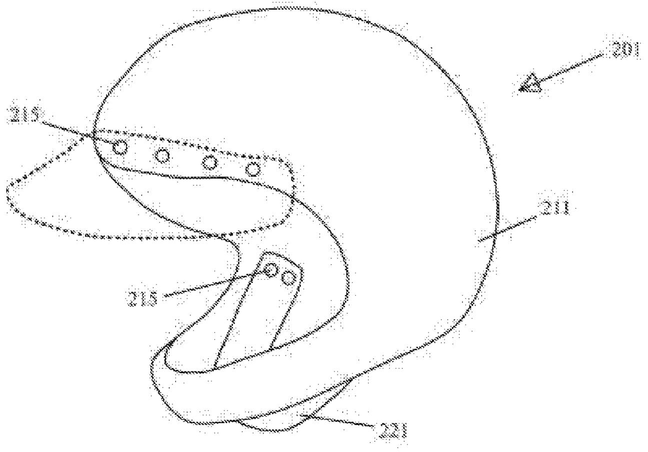
(57) **ABSTRACT**

Protective gear includes an outer shell layer connected to a middle shell layer through an outer energy and impact transformer layer. A padding assembly can be provided over the outer shell layer. The padding assembly can include a padding layer configured to absorb forces normal to the outer shell. The padding assembly can be coupled to the outer shell via an interface layer that allows the padding layer to slide over the outer shell layer in response to tangentially applied forces. The interface layer and associated sliding motion can reduce the tangential forces transmitted through the padding layer to the outer shell while still allowing normal forces to be absorbed. The protective gear may be formed as helmets or body protection for various activities and protect users from not only impact and penetrative forces, but rotational and shear forces as well.





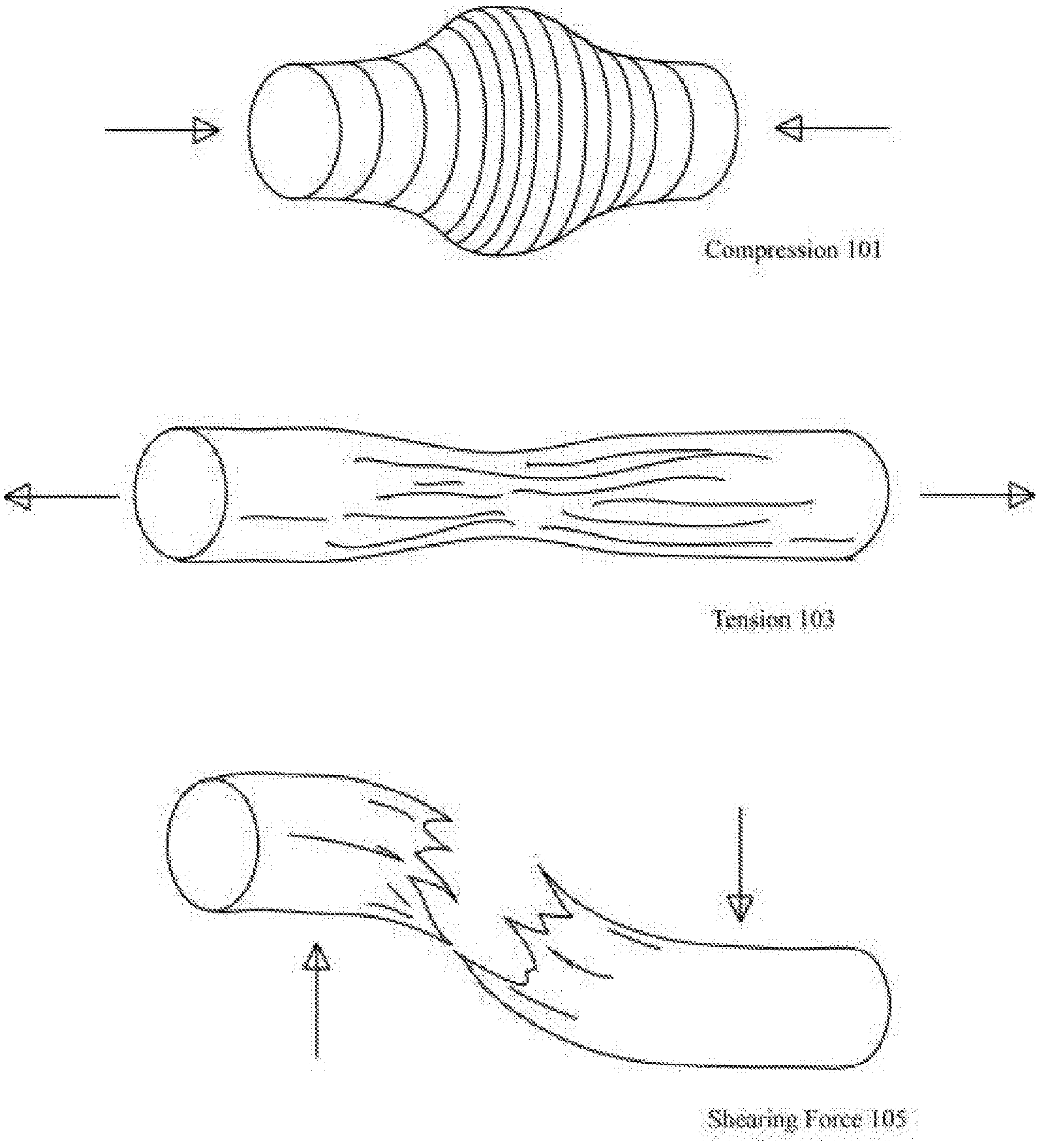


Figure 1

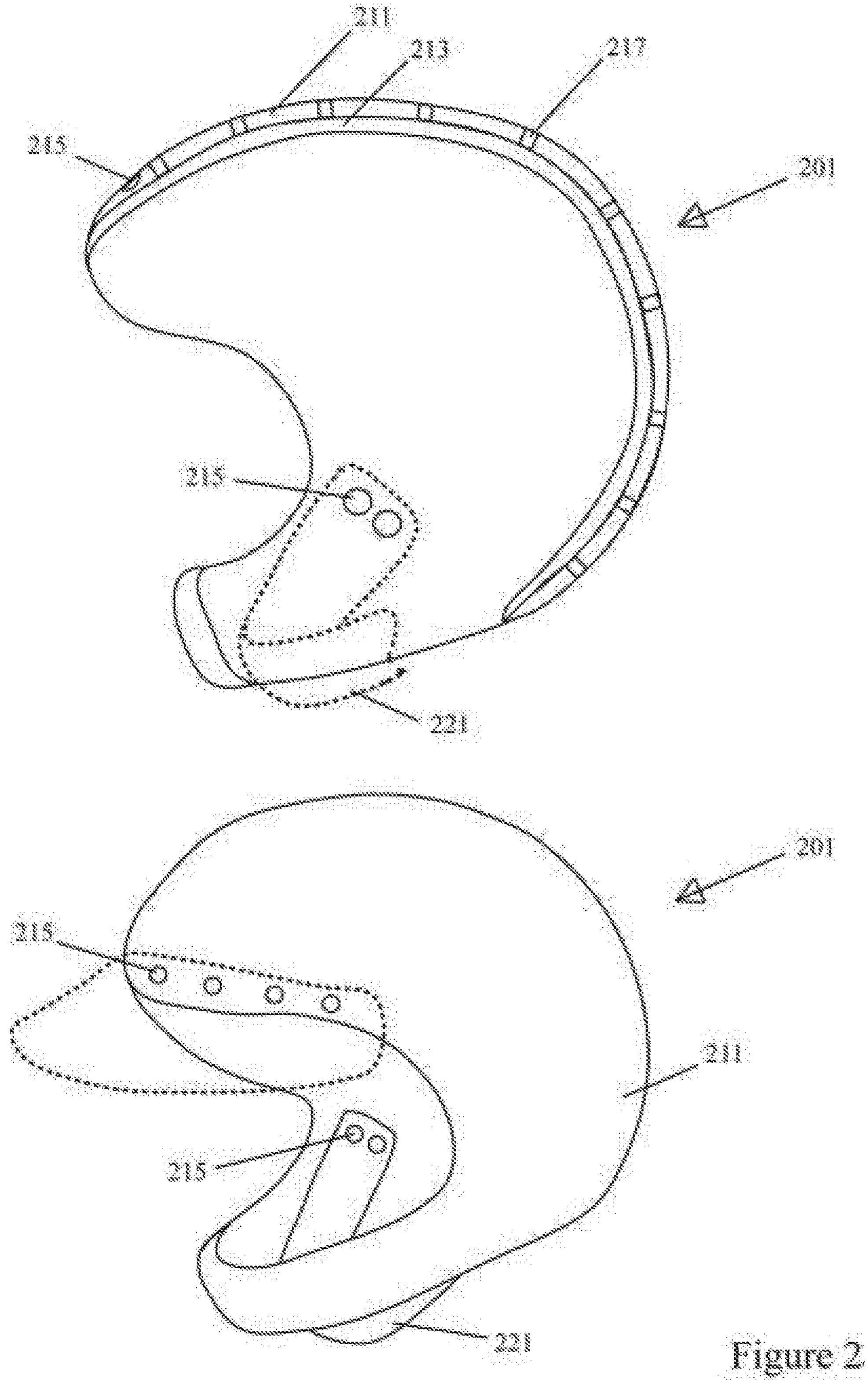


Figure 2

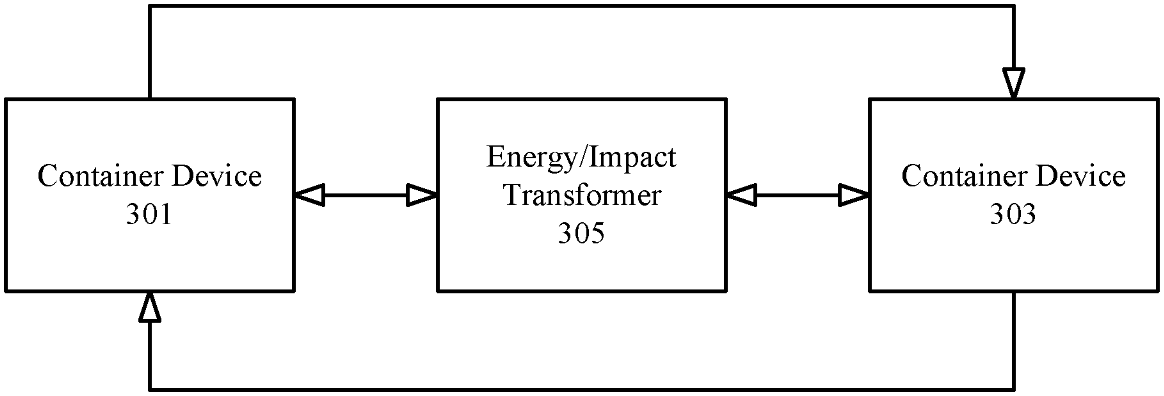

Container Device
301
Energy/Impact
Transformer
305
Container Device
303

Figure 3

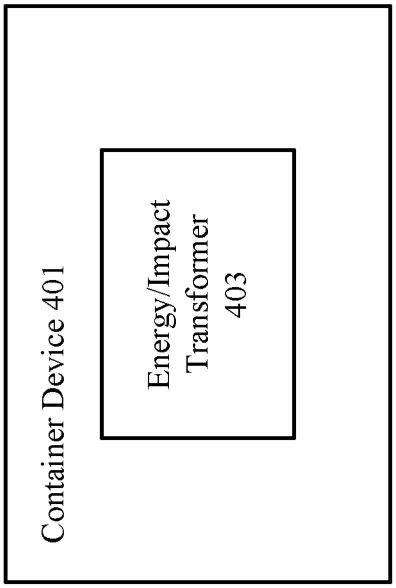


Figure 4

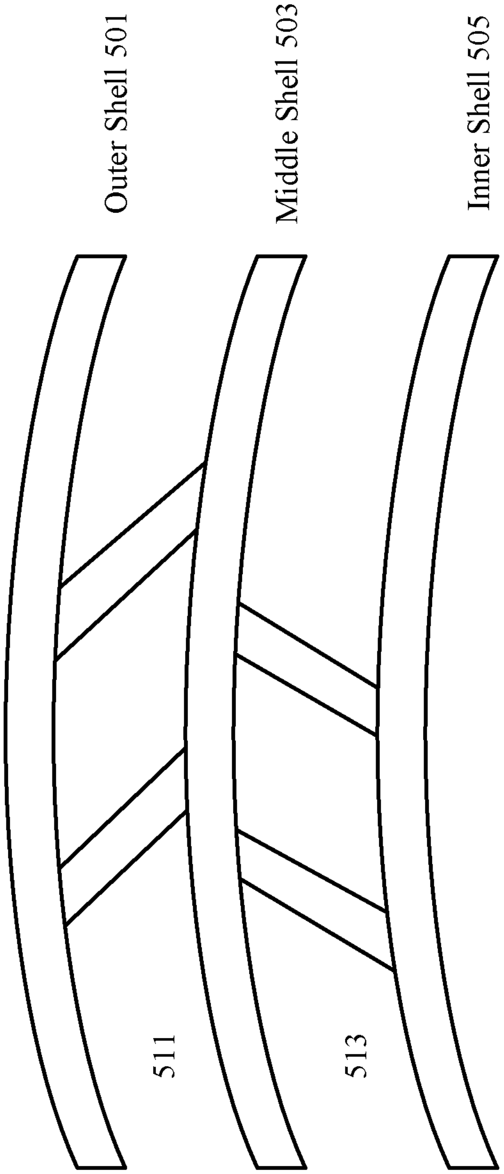
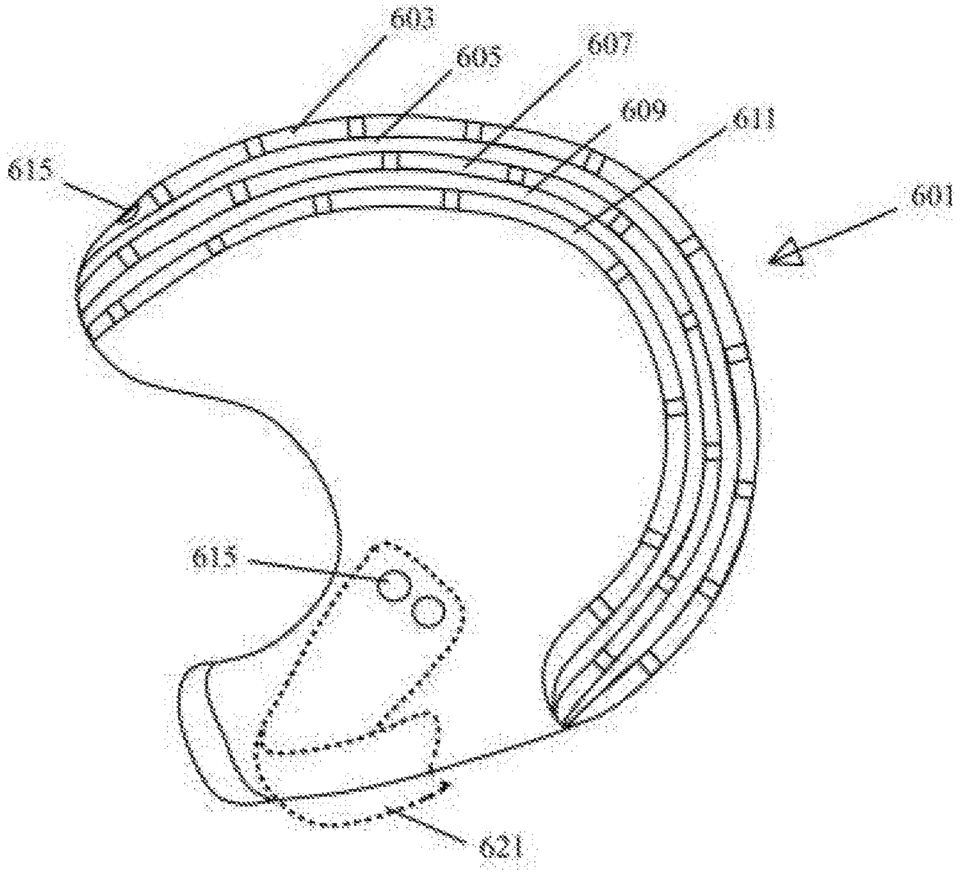


Figure 5



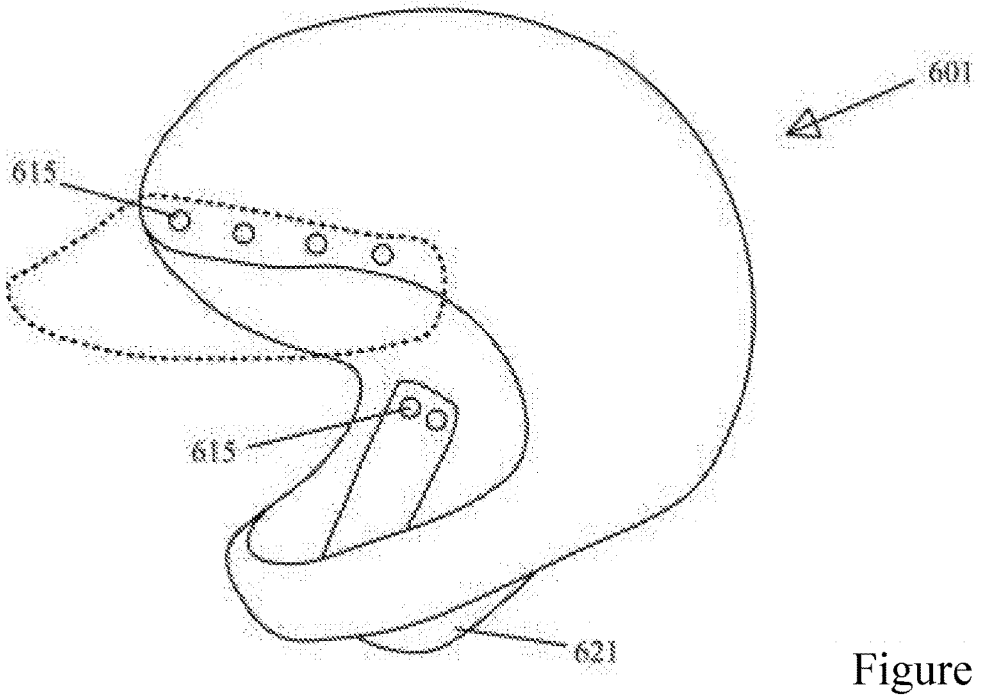


Figure 6

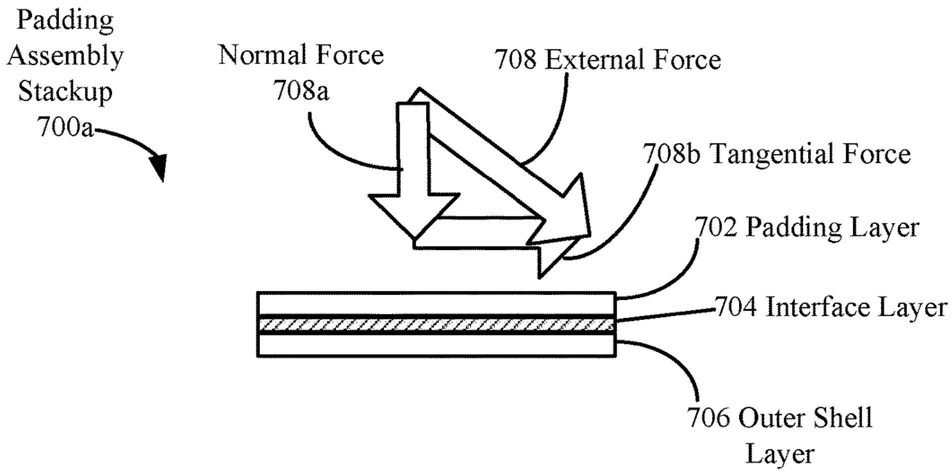


Figure 7A

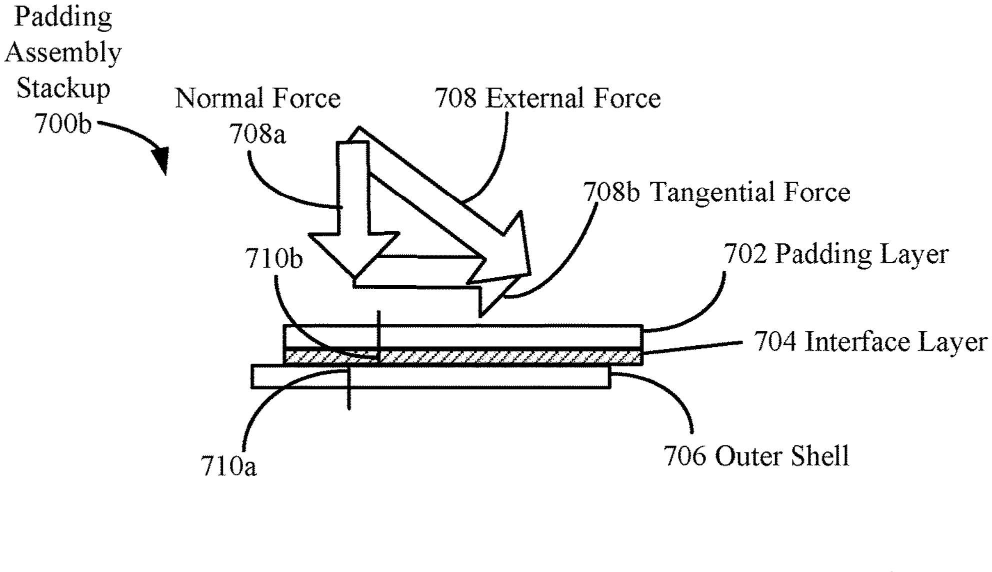


Figure 7B

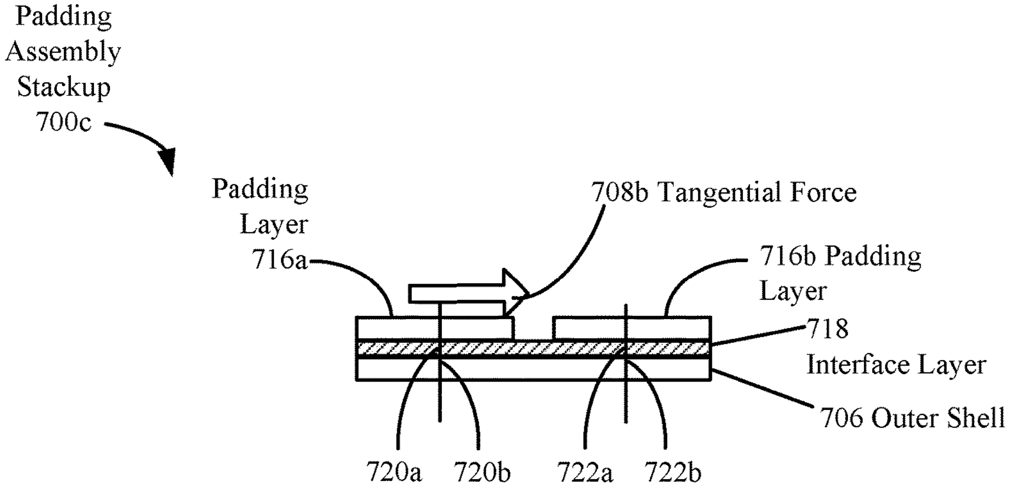


Figure 7C

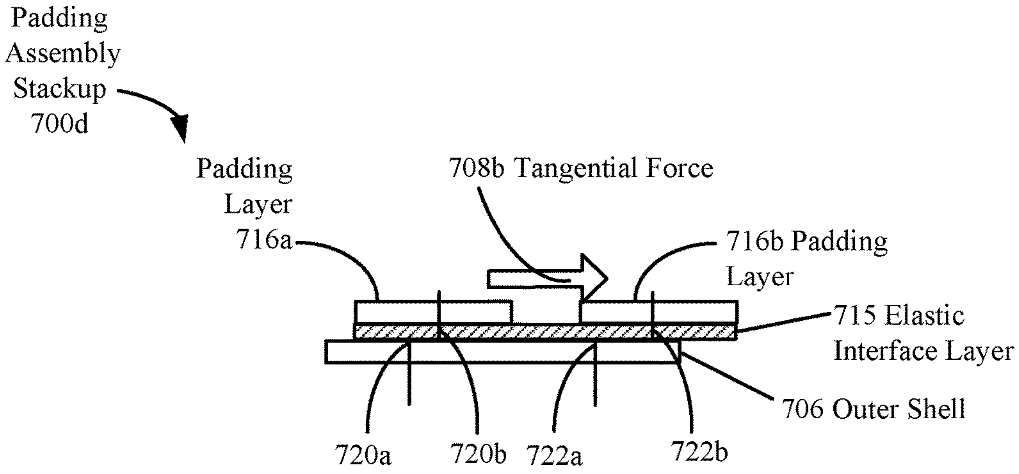


Figure 7D

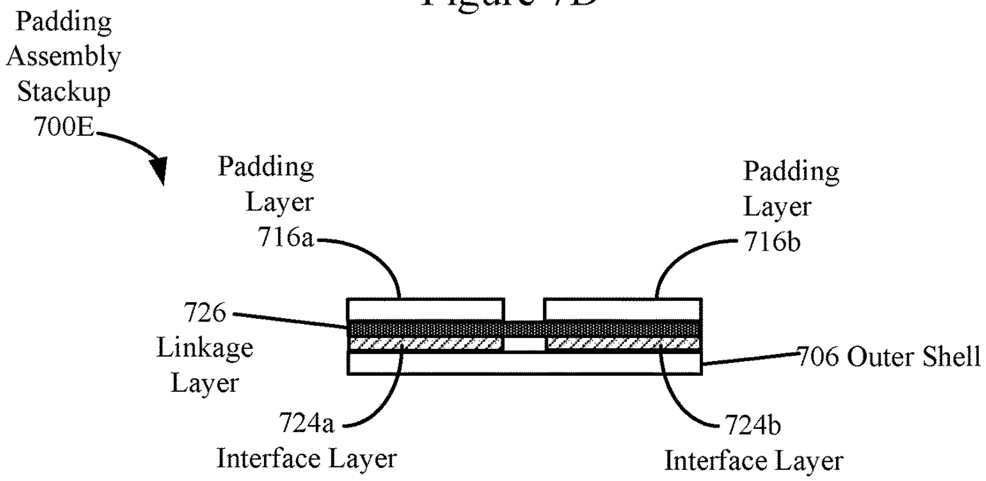


Figure 7E

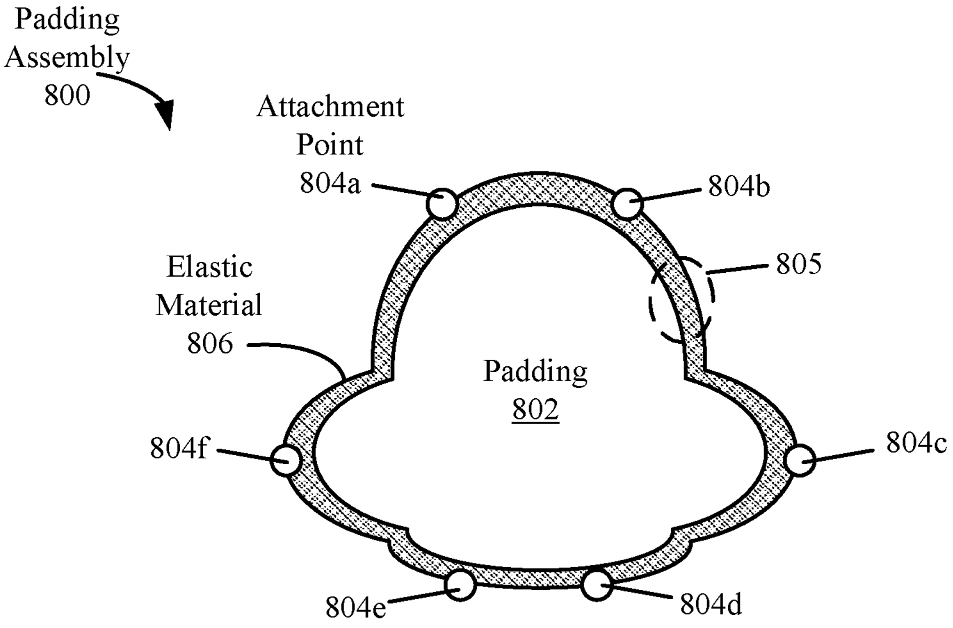


Figure 8A

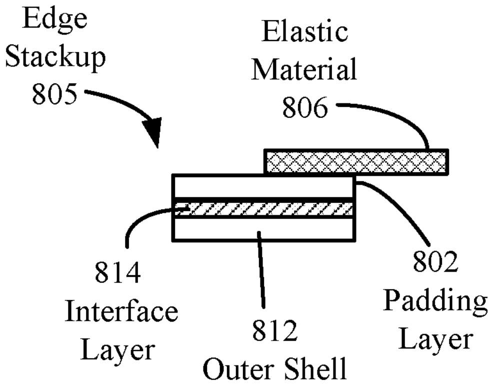


Figure 8B

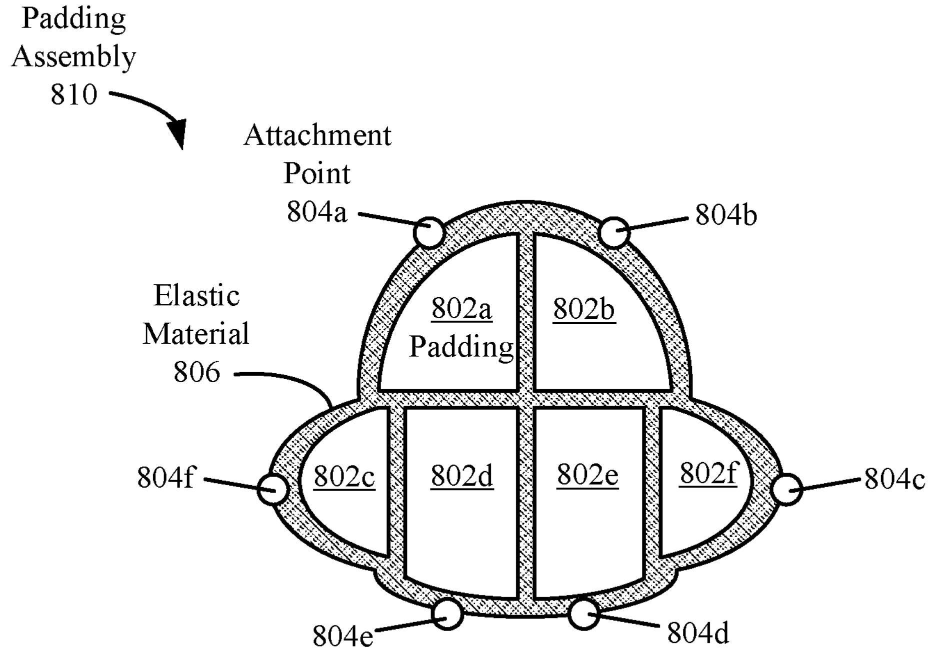


Figure 8C

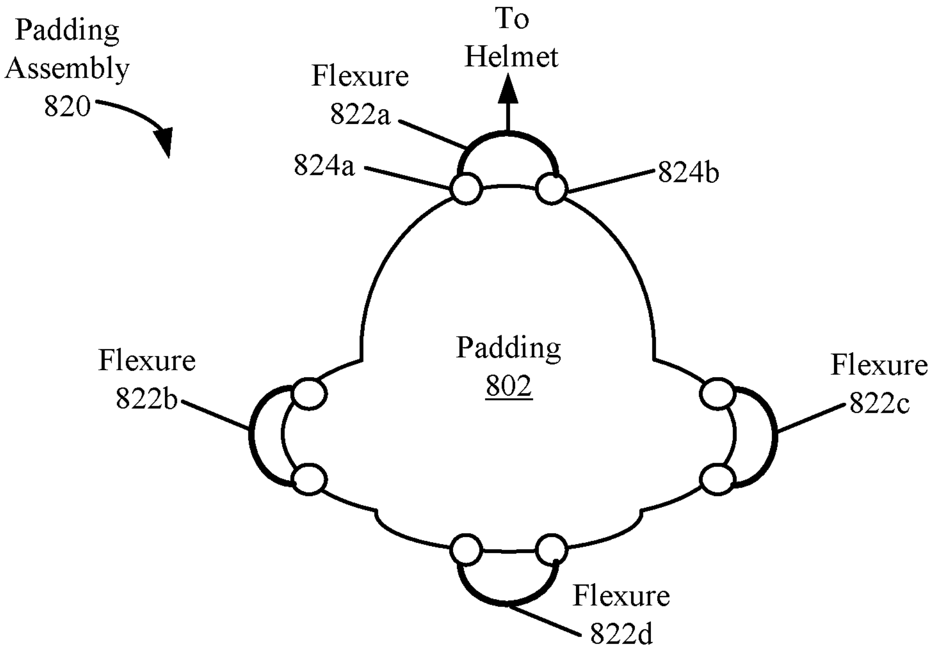


Figure 8D

OUTER PADDING ASSEMBLY FOR BIOMECHANICS AWARE HEADGEAR

TECHNICAL FIELD

[0001] The present disclosure relates to biomechanics aware protective gear.

DESCRIPTION OF RELATED ART

[0002] Protective gear such as sports and safety helmets are designed to reduce direct impact forces that can mechanically damage an area of contact. Protective gear will typically include padding and a protective shell to reduce the risk of physical head injury. Liners are provided beneath a hardened exterior shell to reduce violent deceleration of the head in a smooth uniform manner and in an extremely short distance, as liner thickness is typically limited based on helmet size considerations.

[0003] Protective gear is reasonably effective in preventing injury. Nonetheless, the effectiveness of protective gear remains limited. Consequently, various mechanisms are provided to improve protective gear in a biomechanically aware manner.

SUMMARY

[0004] Protective gear, including an outer shell layer connected to a middle shell layer through an outer energy and impact transformer layer, is described. The protective gear may be formed as helmets or body protection for various activities. The protective gear can protect users from not only impact and penetrative forces, but rotational and shear forces as well.

[0005] A padding assembly can be provided over the outer shell layer. The padding assembly can include a padding layer configured to absorb forces normal to the outer shell. In one embodiment, the padding assembly can be bonded to the outer shell layer. In another embodiment, the padding assembly can be coupled to the outer shell via an interface layer that allows the padding layer to slide over the outer shell layer in response to tangentially applied forces. The interface layer and associated sliding motion can reduce the tangential forces transmitted through the padding layer to the outer shell while still allowing normal forces to be absorbed.

[0006] In one embodiment, a helmet can be provided. The helmet can be generally characterized as including, 1) a first shell layer, 2) a second shell layer connected to an first shell layer through an first energy transformer layer, the first energy transformer layer operable to absorb energy from forces imparted onto the first shell layer, and 3) a padding assembly, disposed above the first shell layer. The first energy transformer layer can include an absorptive/dissipative a material to allow the first shell layer to slide relative to the second shell layer. The padding assembly can include a padding layer and an interface layer which contacts the first shell layer.

[0007] In particular embodiments, the padding layer can be formed from an open-celled foam. Further, the padding layer can be between 1 to 5 mm thick. The interface layer can be an adhesive which bonds the padding layer to the first shell layer.

[0008] In another embodiment, the interface layer, which contacts the first shell layer, can be configured to slide relative to an outer surface of the first shell layer. The interface layer can slide relative to the outer surface in response to tangential forces applied to the padding assembly. In addition, a lining layer connected to the second shell layer can be provided. The lining layer can be configured to conform to a human head.

[0009] Another aspect of the disclosure can be generally characterized as a helmet. The helmet can include 1) a first shell layer, 2) a second shell layer connected to a first shell layer through a first energy transformer layer and 3) a padding assembly, disposed above the first shell layer. The first energy transformer layer can be configured to absorb energy from forces imparted onto the first shell layer where the first energy transformer layer includes an absorptive/dissipative a material to allow the first shell layer to slide relative to the second shell layer.

[0010] The padding assembly can include a padding layer coupled to an interface layer. The interface layer can contact the first shell layer. The interface layer can be configured to slide relative to an outer surface of the first shell layer in response to tangential forces applied to the padding layer.

[0011] In particular embodiments, the padding layer can be formed from an open-celled foam. The padding layer can be between 1 to 5 mm thick. The interface layer can be formed from a hard plastic material. The interface layer can be bonded to the padding layer using an adhesive. A coating can be added to the padding layer to form the interface layer.

[0012] In other embodiments, the padding layer can be formed from a plurality of pieces. The plurality of pieces can be bonded to a contiguous interface layer. The interface layer can formed from an elastic material which allows gaps between the plurality of pieces to dynamically increase in response to the application of the tangential forces and to dynamically decrease when the tangential forces are removed.

[0013] In yet other embodiments, the padding assembly can be formed from a plurality of pieces each of the plurality of pieces including the padding layer and the interface layer. Linkages separate from the padding layer and the interface layer can be used couple the plurality of pieces to one another. The linkages can be formed from an elastic material which, in response to the application of the tangential forces, is configured to stretch to store energy and allow gaps between the plurality of pieces to dynamically increase and which, in response to a removal of the tangential forces, is configured to shrink, to release energy and cause the gaps between the plurality of pieces to dynamically decrease.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The disclosure may best be understood by reference to the following description taken in conjunction with the accompanying drawings, which illustrate particular embodiments.

[0015] FIG. **1** illustrates types of forces on axonal fibers.

[0016] FIG. **2** illustrates one example of a piece of protective gear.

[0017] FIG. **3** illustrates one example of a container device system.

[0018] FIG. **4** illustrates another example of a container device system.

[0019] FIG. **5** illustrates one example of a multiple shell system.

[0020] FIG. **6** illustrates one example of a multiple shell helmet.

[0021] FIGS. **7**A-**7**E illustrate padding assembly stackups and helmet interfaces.

[0022] FIGS. **8**A-**8**D illustrate padding assemblies for a helmet.

DESCRIPTION OF EXAMPLE EMBODIMENTS

[0023] Reference will now be made in detail to some specific examples of the invention including the best modes contemplated by the inventors for carrying out the invention. Examples of these specific embodiments are illustrated in the accompanying drawings. While the invention is described in conjunction with these specific embodiments, it will be understood that it is not intended to limit the invention to the described embodiments. On the contrary, it is intended to cover alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

[0024] For example, the techniques of the present invention will be described in the context of helmets. However, it should be noted that the techniques of the present invention apply to a wide variety of different pieces of protective gear. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. Particular example embodiments of the present invention may be implemented without some or all of these specific details. In other instances, well known process operations have not been described in detail in order not to unnecessarily obscure the present invention.

[0025] Various techniques and mechanisms of the present invention will sometimes be described in singular form for clarity. However, it should be noted that some embodiments include multiple iterations of a technique or multiple instantiations of a mechanism unless noted otherwise. For example, a protective device may use a single strap in a variety of contexts. However, it will be appreciated that a system can use multiple straps while remaining within the scope of the present invention unless otherwise noted. Furthermore, the techniques and mechanisms of the present invention will sometimes describe a connection between two entities. It should be noted that a connection between two entities does not necessarily mean a direct, unimpeded connection, as a variety of other entities may reside between the two entities. For example, different layers may be connected using a variety of materials. Consequently, a connection does not necessarily mean a direct, unimpeded connection unless otherwise noted.

Overview

[0026] Protective gear includes an outer shell layer connected to a middle shell layer through an outer energy and impact transformer layer. The middle shell layer is connected to an inner shell layer through an inner energy and impact transformer layer. The outer and inner energy and impact transformer layers flexibly connect the shell layers to absorb impact forces, rotational forces, shear forces, etc., and allow the various shell layers to move and slide relative to the other shell layers. The outer and inner energy and impact transformer layers may be constructed using gels, fluids, electro-rheological elements, magneto-rheological elements, etc. The protective gear may be formed as helmets or body protection for various activities and may be used to protect users from not only impact and penetrative forces, but rotational and shear forces as well.

Example Embodiments

[0027] Protective gear such as knee pads, shoulder pads, and helmets are typically designed to prevent direct impact injuries or trauma. For example, many pieces of protective gear reduce full impact forces that can structurally damage an area of contact such as the skull or knee. Major emphasis is placed on reducing the likelihood of cracking or breaking of bone. However, the larger issue is preventing the tissue and neurological damage caused by rotational forces, shear forces, oscillations, and tension/compression forces.

[0028] For head injuries, the major issue is neurological damage caused by oscillations of the brain in the cranial vault resulting in coup-contracoup injuries manifested as direct contusions to the central nervous system (CNS), shear injuries exacerbated by rotational, tension, compression, and/or shear forces resulting in demyelination and tearing of axonal fibers; and subdural or epidural hematomas. Because of the emphasis in reducing the likelihood of cracking or breaking bone, many pieces of protective gear do not sufficiently dampen, transform, dissipate, and/or distribute the rotational, tension, compression, and/or shear forces, but rather focus on absorbing the direct impact forces over a small area, potentially exacerbating the secondary forces on the CNS. Initial mechanical damage results in a secondary cascade of tissue and cellular damage due to increased glutamate release or other trauma induced molecular cascades.

[0029] Traumatic brain injury (TBI) has immense personal, societal and economic impact. The Center for Disease Control and Prevention documented 1.4 million cases of TBI in the USA in 2007. This number was based on patients with a loss of consciousness from a TBI resulting in an Emergency Room visit. With increasing public awareness of TBI this number increased to 1.7 million cases in 2010. Of these cases there were 52,000 deaths and 275,000 hospitalizations, with the remaining 1.35 million cases released from the ER. Of these 1.35 million discharged cases at least 150,000 people will have significant residual cognitive and behavioral problems at 1-year post discharge from the ER. Notably, the CDC believes these numbers under represent the problem since many patients do not seek medical evaluation for brief loss of consciousness due to a TBI. These USA numbers are similar to those observed in other developed countries and are likely higher in third-world countries with poorer vehicle and head impact protection. To put the problem in a clearer perspective, the World Health Organization (WHO) anticipates that TBI will become a leading cause of death and disability in the world by the year 2020.

[0030] The CDC numbers do not include head injuries from military actions. Traumatic brain injury is widely cited as the "signature injury" of Operation Enduring Freedom and Operation Iraqi Freedom. The nature of warfare conducted in Iraq and Afghanistan is different from that of previous wars and advances in protective gear including helmets as well as improved medical response times allow soldiers to survive events such as head wounds and blast exposures that previously would have proven fatal. The introduction of the Kevlar helmet has drastically reduced field deaths from bullet and shrapnel wounds to the head. However, this increase in survival is paralleled by a dramatic increase in residual brain injury from compression and rotational forces to the brain in TBI survivors. Similar to that observed in the civilian population the residual effects of military deployment related TBI are neurobehavioral symptoms such as cognitive deficits and emotional and somatic complaints. The statistics provided by the military cite an incidence of 6.2% of head injuries in combat zone veterans. One might expect these numbers to hold in other countries.

[0031] In addition to the incidence of TBI in civilians from falls and vehicular accidents or military personnel in combat there is increasing awareness that sports-related repetitive forces applied to the head with or without true loss of consciousness can have dire long-term consequences. It has been known since the 1920's that boxing is associated with devastating long-term issues including "dementia pugilistica" and Parkinson-like symptoms (i.e. Mohammed Ali). We now know that this repetitive force on the brain dysfunction extends to many other sports. Football leads the way in concussions with loss of consciousness and post-traumatic memory loss (63% of all concussions in all sports), wrestling comes in second at 10% and soccer has risen to 6% of all sports related TBIs. In the USA 63,000 high school students suffer a TBI per year and many of these students have persistent long-term cognitive and behavioral issues. This disturbing pattern extends to professional sports where impact forces to the body and head are even higher due to the progressive increase in weight and speed of professional athletes. Football has dominated the national discourse in the area but serious and progressive long-term neurological issues are also seen in hockey and soccer players and in any sport with the likelihood of a TBI. Repetitive head injuries result in progressive neurological deterioration with neuropathological findings mimicking Alzheimer's disease. This syndrome with characteristic post-mortem neuropathological findings on increases in Tau proteins and amyloid plaques is referred to as Chronic Traumatic Encephalopathy (CTE).

[0032] The human brain is a relatively delicate organ weighing about 3 pounds and having a consistency a little denser than gelatin and close to that of the liver. From an evolutionary perspective, the brain and the protective skull were not designed to withstand significant external forces. Because of this poor impact resistance design, external forces transmitted through the skull to the brain that is composed of over 100 billion cells and up to a trillion connecting fibers results in major neurological problems. These injuries include contusions that directly destroy brain cells and tear the critical connecting fibers necessary to transmit information between brain cells.

[0033] Contusion injuries are simply bleeding into the substance of the brain due to direct contact between the brain and the bony ridges of the inside of the skull. Unfortunately, the brain cannot tolerate blood products and the presence of blood kicks off a biological cascade that further damages the brain. Contusions are due to the brain oscillating inside the skull when an external force is applied. These oscillations can include up to three cycles back and forth in the cranial vault and are referred to as coup-contra coup injuries. The coup part of the process is the point of contact of the brain with the skull and the contra-coup is the next point of contact when the brain oscillates and strikes the opposite part of the inside of the skull.

[0034] The inside of the skull has a series of sharp bony ridges in the front of the skull and when the brain is banged against these ridges it is mechanically torn resulting in a contusion. These contusion injuries are typically in the front of the brain damaging key regions involved in cognitive and emotional control.

[0035] Shear injuries involve tearing of axonal fibers. The brain and its axonal fibers are extremely sensitive to rotational forces. Boxers can withstand hundreds of punches directly in the face but a single round-house punch or upper cut where the force comes in from the side or bottom of the jaw will cause acute rotation of the skull and brain and typically a knock-out. If the rotational forces are severe enough, the result is tearing of axons.

[0036] FIG. **1** below shows how different forces affect axons. Compression **101** and tension **103** can remove the protective coating on an axon referred to as a myelin sheath. The myelin can be viewed as the rubber coating on a wire. If the internal wire of the axon is not cut the myelin can re-grow and re-coat the "wire" which can resume axonal function and brain communication. If rotational forces are significant, shear forces **105** tear the axon. This elevates the problem since the ends of cut axons do not re-attach. This results in a permanent neurological deficit and is referred to as diffuse axonal injury (DAI), a major cause of long-term neurological disability after TBI.

[0037] Some more modern pieces of protective gear have been introduced with the awareness that significant injuries besides musculoskeletal or flesh injuries in a variety of activities require new protective gear designs.

[0038] U.S. Pat. No. 7,076,811 issued to Puchalski describes a helmet with an impact absorbing crumple or shear zone. "The shell consists of three (or more) discrete panels that are physically and firmly coupled together providing rigid protection under most circumstances, but upon impact the panels move relative to one another, but not relative to the user's head, thereby permitting impact forces to be dissipated and/or redirected away from the cranium and brain within. Upon impact to the helmet, there are sequential stages of movement of the panels relative to each other, these movements initially being recoverable, but with sufficient vector forces the helmet undergoes structural changes in a pre-determined fashion, so that the recoverable and permanent movements cumulatively provide a protective 'crumple zone' or 'shear zone'."

[0039] U.S. Pat. No. 5,815,846 issued to Calonge describes "An impact resistant helmet assembly having a first material layer coupled to a second material layer so as to define a gas chamber therebetween which contains a quantity that provides impact dampening upon an impact force being applied to the helmet assembly. The helmet assembly further includes a containment layer disposed over the second material layer and structured to define a fluid chamber in which a quantity of fluid is disposed. The fluid includes a generally viscous gel structured to provide some resistance against disbursement from an impacted region of the fluid chamber to non-impacted regions of the fluid chamber, thereby further enhance the impact distribution and dampening of the impact force provided by the helmet assembly."

[0040] U.S. Pat. No. 5,956,777 issued to Popovich describes "A helmet for protecting a head by laterally displacing impact forces, said helmet comprising: a rigid inner shell formed as a single unit; a resilient spacing layer disposed outside of and in contact with said inner shell; and an articulated shell having a plurality of discrete rigid segments disposed outside of and in contact with said resilient spacing layer and a plurality of resilient members which couple adjacent ones of said rigid segments to one another."

[0041] U.S. Pat. No. 6,434,755 issued to Halstead describes a football helmet with liner sections of different thicknesses and densities. The thicker, softer sections would handle less intense impacts, crushing down until the thinner, harder sections take over to prevent bottoming out.

[0042] Still other ideas relate to using springs instead of crushable materials to manage the energy of an impact. Springs are typically associated with rebound, and energy stored by the spring is returned to the head. This may help in some instances, but can still cause significant neurological injury. Avoiding energy return to the head is a reason that non-rebounding materials are typically used.

[0043] Some of the protective gear mechanisms are not sufficiently biomechanically aware and are not sufficiently customized for particular areas of protection. These protective gear mechanisms also are not sufficiently active at the right time scales to avoid damage. For example, in many instances, materials like gels may only start to convert significant energy into heat after significant energy has been transferred to the brain. Similarly, structural deformation mechanisms may only break and absorb energy after a significant amount of energy has been transferred to the brain.

[0044] Current mechanisms are useful for particular circumstances but are limited in their ability to protect against numerous types of neurological damage. Consequently, an improved smart biomechanics aware and energy conscious protective gear mechanism is provided to protect against mechanical damage as well as neurological damage.

[0045] According to various embodiments, protective gear such as a helmet includes a container device to provide a structural mechanism for holding an energy and impact transformer. The design of this element could be a part of the smart energy conscious biomechanics aware design for protection. The energy and impact transformer includes a mechanism for the dissipation, transformation, absorption, redirection or force/energy at the right time scales (in some cases as small as a few milliseconds or hundreds of microseconds).

[0046] In particular embodiments, the container mechanism provides structure to allow use of an energy and impact transformer. The container mechanism may be two or three shells holding one or more layers of energy and impact transformer materials. That is, a multiple shell structure may have energy and impact transformer materials between adjacent shell layers. The shells may be designed to prevent direct penetration from any intruding or impeding object. In some examples, the outer shell may be associated with mechanisms for impact distribution, energy transformation, force dampening, and shear deflection and transformation. In some examples, the container mechanism can be constructed of materials such as polycarbonate, fiberglass, Kevlar, metal, alloys, combinations of materials, etc.

[0047] According to various embodiments, the energy and impact transformer provides a mechanism for the dissipation, transformation, absorption, and redirection of force and energy at the appropriate time scales. The energy and impact transformer may include a variety of elements. In some examples, a mechanical transformer element connects multiple shells associated with a container mechanism with mechanical structures or fluids that help transform the impact or shear forces on an outer shell into more benign forces or energy instead of transferring the impact or shear forces onto an inner shell.

[0048] In some examples, a mechanical transformer layer is provided between each pair of adjacent shells. The mechanical transform may use a shear truss-like structure connecting an outer shell and an inner shell that dampens any force or impact. In some examples, shear truss structure layers connect an outer shell to a middle shell and the middle shell to an inner shell. According to various embodiments, the middle shell or center shell may slide relative to the inner shell and reduce the movement and/or impact imparted on an outer shell. In particular embodiments, the outer shell may slide up to several centimeters relative to the middle shell. In particular embodiments, the material used for connecting the middle shell to the outer shell or the inner shell could be a material that absorbs/dissipates mechanical energy as thermal energy or transformational energy. The space between the outer shell, the middle shell, and the inner shell can be filled with absorptive/dissipative material such as fluids and gels.

[0049] According to various embodiments, the energy and impact transformer may also include an electro-rheological element. Different shells may be separated by an electro-rheological element with electric field dependent viscosity. The element may essentially stay solid most of the time. When there is stress/strain on an outer shell, the electric field is activated so that the viscosity changes depending on the level of stress/strain. Shear forces on an inner shell are reduced to minimize impact transmission.

[0050] In particular embodiments, the energy and impact transformer also includes a magneto-rheological element. Various shells may be separated by magneto rheological elements with magnetic field dependent viscosity. The element may essentially stay solid most of the time. When there is stress/strain on an outer shell, the magnetic field is activated so that the viscosity changes depending on the level of stress/strain. Shear forces on an inner shell are reduced to minimize impact transmission.

[0051] Electro-rheological and magneto-rheological elements may include smart fluids with properties that change in the presence of electric field or a magnetic field. Some smart fluids undergo changes in viscosity when a magnetic field is applied. For example, a smart fluid may change from a liquid to a gel when magnets line up to create a magnetic field. Smart fluids may react within milliseconds to reduce impact and shear forces between shells.

[0052] In other examples, foam and memory foam type elements may be included to absorb and distribute forces. In some examples, foam and memory foam type elements may reside beneath the inner shell. A magnetic suspension element may be used to actively or passively reduce external forces. An inner core and an outer core may be separated by magnets that resist each other, e.g. N-poles opposing each other. The inner and outer cores naturally would want to move apart, but are pulled together by elastic materials. When an outer shell is impact and the magnets are pushed closer, forces between the magnets increase through the air gap.

[0053] According to various embodiments, a concentric geodesic dome element includes a series of inner shells, each of which is a truss based geodesic dome, but connected to the outer geodesic through structural or fluidic mechanisms. This allows each geodesic structure to fully distribute its own shock load and transmit it in a uniform manner to the dome underneath. The sequence of geodesic structures and the separation by fluid provides uniform force distribution and/or dissipation that protects the inner most shell from these impacts.

[0054] In particular embodiments, a fluid/accordion element would separate an inner shell and an outer shell using an accordion with fluid/gel in between. This would allow shock from the outer core to be transmitted and distributed through the enclosed fluid uniformly while the accordion compresses to accommodate strain. A compressed fluid/piston/spring element could include piston/cylinder like elements with a compressed fluid in between that absorbs the impact energy while increasing the resistance to the applied force. The design could include additional mechanical elements like a spring to absorb/dissipate the energy.

[0055] In still other examples, a fiber element involves using a rippled outer shell with texture like that of a coconut. The outer shell may contain dense coconut fiber like elements that separate the inner core from the outer core. The shock can be absorbed by the outer core and the fibrous filling. Other elements may also be included in an inner core structure. In some examples, a thick stretchable gel filled bag wrapped around the inner shell could expand and contract in different areas to instantaneously transfer and distribute forces. The combination of the elasticity of a bag and the viscosity of the gel could provide for cushioning to absorb/dissipate external forces.

[0056] According to various embodiments, a container device includes multiple shells such as an outer shell, a middle shell, and an inner shell. The shells may be separated by energy and impact transformer mechanisms. In some examples, the shells and the energy and impact transformer mechanisms can be integrated or a shell can also operate as an energy and impact transformer.

[0057] FIG. **2** illustrates one example of a particular piece of protective gear. Helmet **201** includes a shell layer **211** and a lining layer **213**. The shell layer **211** includes attachment points **215** for a visor, chin bar, face guard, face cage, or face protection mechanism generally. In some examples, the shell layer **211** includes ridges **217** and/or air holes for breathability. The shell layer **211** may be constructed using plastics, resins, metal, composites, etc. In some instances, the shell layer **211** may be reinforced using fibers such as aramids. The shell layer **211** helps to distribute mechanical energy and prevent penetration. The shell layer **211** is typically made using lighter weight materials to prevent the helmet itself from causing injury.

[0058] According to various embodiments, a chin strap **221** is connected to the helmet to secure helmet positioning. The shell layer **211** is also sometimes referred to as a container or a casing. In many examples, the shell layer **211** covers a lining layer **213**. The lining layer **213** may include lining materials, foam, and/or padding to absorb mechanical energy and enhance fit. A lining layer **213** may be connected to the shell layer **211** using a variety of attachment mechanisms such as glue or Velcro. According to various embodiments, the lining layer **213** is pre-molded to allow for enhanced fit and protection. According to various embodiments, the lining layer may vary, e.g. from 4 mm to 40 mm in thickness, depending on the type of activity a helmet is designed for. In some examples, custom foam may be injected into a fitted helmet to allow for personalized fit. In other examples, differently sized shell layers and lining layers may be provided for various activities and head sizes.

[0059] The shell layer **211** and lining layer **213** protect the skull nicely and have resulted in a dramatic reduction in skull fractures and bleeding between the skull and the brain (subdural and epidural hematomas). Military helmets use Kevlar to decrease penetrating injuries from bullets, shrapnel etc. Unfortunately, these approaches are not well designed to decrease direct forces and resultant coup-contra coup injuries that result in both contusions and compression-tension axon injuries. Furthermore, many helmets do not protect against rotational forces that are a core cause of a shear injury and resultant long-term neurological disability in civilian and military personnel. Although the introduction of Kevlar in military helmets has decreased mortality from penetrating head injuries, the survivors are often left with debilitating neurological deficits due to contusions and diffuse axonal injury.

[0060] FIG. **3** illustrates one example of a container device system. According to various embodiments, protective gear includes multiple container devices **301** and **303**. In particular embodiments, the multiple container devices are loosely interconnected shells holding an energy and impact transformer **305**. The multiple container devices may be multiple plastic and/or resin shells. In some examples, the containers devices **301** and **303** may be connected only through the energy and impact transformer **305**. In other examples, the container devices **301** and **303** may be loosely connected in a manner supplementing the connection by the energy and impact transformer **305**.

[0061] According to various embodiments, the energy and impact transformer **305** may use a shear truss-like structure connecting the container **301** and container **303** to dampen any force or impact. In some examples, the energy and impact transformer **305** allows the container **301** to move or slide with respect to container **303**. In some examples, up to several centimeters of relative movement is allowed by the energy and impact transformer **305**.

[0062] In particular embodiments, the energy and impact transformer **305** could be a material that absorbs/dissipates mechanical energy as thermal energy or transformational energy and may include electro-rheological, magneto-rheological, foam, fluid, and/or gel materials.

[0063] FIG. **4** illustrates another example of a container device system. Container **401** encloses energy and impact transformer **403**. In some examples, multiple containers or multiple shells may not be necessary. The container may be constructed using plastic and/or resin. And may expand or contract with the application of force. The energy and impact transformer **403** may similarly expand or contract with the application of force. The energy and impact transformer **403** may receive and convert energy from physical impacts on a container **401**.

[0064] FIG. **5** illustrates one example of a multiple shell system. An outer shell **501**, a middle shell **503**, and an inner shell **505** may hold energy and impact transformative layers **511** and **513** between them. Energy and impact transformer layer **511** residing between shells **501** and **503** may allow shell **501** to move and/or slide with respect to middle shell **503**. By allowing sliding movements that convert potential head rotational forces into heat or transformation energy, shear forces can be significantly reduced.

[0065] Similarly, middle shell **503** can move and slide with respect to inner shell **505**. In some examples, the amount of movement and/or sliding depends on the viscosity of fluid in the energy and impact transformer layers **511** and

513. The viscosity may change depending on electric field or voltage applied. In some other examples, the amount of movement and/or sliding depends on the materials and structures of materials in the energy and impact transformer layers **511** and **513**.

[0066] According to various embodiments, when a force is applied to an outer shell **501**, energy is transferred to an inner shell **505** through a suspended middle shell **503**. The middle shell **503** shears relative to the top shell **501** and inner shell **505**. In particular embodiments, the energy and impact transformer layers **511** and **513** may include thin elastomeric trusses between the shells in a comb structure. The energy and impact transformer layers **511** and **513** may also include energy dampening/absorbing fluids or devices.

[0067] According to various embodiments, a number of different physical structures can be used to form energy and impact transformer layers **511** and **513**. In some examples, energy and impact transformer layer **511** includes a layer of upward or downward facing three dimensional conical structures separating outer shell **501** and middle shell **503**. Energy and impact transformer layer **513** includes a layer of upward or downward facing conical structures separating middle shell **503** and inner shell **505**. The conical structures in energy and impact transformer layer **511** and the conical structures in energy and impact transformer layer **513** may or may not be aligned. In some examples, the conical structures in layer **511** are misaligned with the conical structures in layer **513** to allow for improved shear force reduction.

[0068] In some examples, conical structures are designed to have a particular elastic range where the conical structures will return to the same structure after force applied is removed. The conical structures may also be designed to have a particular plastic range where the conical structure will permanently deform if sufficient rotational or shear force is applied. The deformation itself may dissipate energy but would necessitate replacement or repair of the protective gear.

[0069] Conical structures are effective in reducing shear, rotational, and impact forces applied to an outer shell **501**. Conical structures reduce shear and rotational forces applied from a variety of different directions. According to various embodiments, conical structures in energy and impact transformer layers **511** are directed outwards with bases situated on middle shell **503** and inner shell **505** respectively. In some examples, structures in the energy and impact transformer layer may be variations of conical structures, including three dimensional pyramid structures and three dimensional parabolic structures. In still other examples, the structures may be cylinders,

[0070] FIG. **6** illustrates one example of a multiple shell helmet. According to various embodiments, helmet **601** includes an outer shell layer **603**, an outer energy and impact transformer **605**, a middle shell layer **607**, an inner energy and impact transformer **609**, and an inner shell layer **611**. The helmet **601** may also include a lining layer within the inner shell layer **611**. In particular embodiments, the inner shell layer **611** includes attachment points **615** for a chin strap for securing helmet **601**. In particular embodiments, the outer shell layer **603** includes attachment points for a visor, chin bar, face guard, face cage, and/or face protection mechanism **615** generally. In some examples, the inner shell layer **611**, middle shell layer **607**, and outer shell layer **603** includes ridges **617** and/or air holes for breathability. The outer shell layer **603**, middle shell layer **607**, and inner shell layer **611** may be constructed using plastics, resins, metal, composites, etc. In some instances, the outer shell layer **603**, middle shell layer **607**, and inner shell layer **611** may be reinforced using fibers such as aramids. The energy and impact transformer layers **605** and **609** can help distribute mechanical energy and shear forces so that less energy is imparted on the head.

[0071] According to various embodiments, a chin strap **621** is connected to the inner shell layer **611** to secure helmet positioning. The various shell layers are also sometimes referred to as containers or casings. In many examples, the inner shell layer **611** covers a lining layer (not shown). The lining layer may include lining materials, foam, and/or padding to absorb mechanical energy and enhance fit. A lining layer may be connected to the inner shell layer **611** using a variety of attachment mechanisms such as glue or Velcro. According to various embodiments, the lining layer is pre-molded to allow for enhanced fit and protection. According to various embodiments, the lining layer may vary, e.g. from 4 mm to 40 mm in thickness, depending on the type of activity a helmet is designed for. In some examples, custom foam may be injected into a fitted helmet to allow for personalized fit. In other examples, differently sized shell layers and lining layers may be provided for various activities and head sizes.

[0072] The middle shell layer **607** may only be indirectly connected to the inner shell layer **611** through energy and impact transformer **609**. In particular embodiments, the middle shell layer **607** floats above inner shell layer **611**. In other examples, the middle shell layer **607** may be loosely connected to the inner shell layer **611**. In the same manner, outer shell layer **603** floats above middle shell layer **607** and may only be connected to the middle shell layer through energy and impact transformer **605**. In other examples, the outer shell layer **603** may be loosely and flexibly connected to middle shell layer **607** and inner shell layer **611**. The shell layers **603**, **607**, and **611** provide protection against penetrating forces while energy and impact transformer layers **605** and **609** provide protection against compression forces, shear forces, rotational forces, etc. According to various embodiments, energy and impact transformer layer **605** allows the outer shell **603** to move relative to the middle shell **607** and the energy and impact transformer layer **609** allows the outer shell **603** and the middle shell **607** to move relative to the inner shell **611**. Compression, shear, rotation, impact, and/or other forces are absorbed, deflected, dissipated, etc., by the various layers.

[0073] According to various embodiments, the skull and brain are not only provided with protection against skull fractures, penetrating injuries, subdural and epidural hematomas, but also provided with some measure of protection against direct forces and resultant coup-contra coup injuries that result in both contusions and compression-tension axon injuries. The skull is also protected against rotational forces that are a core cause of a shear injury and resultant long-term neurological disability in civilian and military personnel.

[0074] In some examples, the energy and impact transformer layers **605** and **609** may include passive, semi-active, and active dampers. According to various embodiments, the outer shell **603**, middle shell **607**, and the inner shell **611** may vary in weight and strength. In some examples, the outer shell **603** has significantly more weight, strength, and structural integrity than the middle shell **607** and the inner shell **611**. The outer shell **603** may be used to prevent penetrating forces, and consequently may be constructed using higher strength materials that may be more expensive or heavier.

[0075] Outer Padding Assembly

[0076] In this section, embodiments of a padding assembly for a protective gear, such as a helmet, are described. The padding assembly can be mounted to an outer shell layer of the protective gear. As described above, the protective gear can include an outer shell layer connected to a middle shell layer through an outer energy and impact transformer layer. In one embodiment, the padding assembly can be bonded to the outer shell layer such that it moves with the outer shell layer in response to an application of tangential forces. In another embodiment, the padding assembly can be configured to slide relative to the outer shell layer in response to an application of tangential forces.

[0077] FIGS. 7A-7H illustrate padding assembly stackups and helmet interfaces. In FIG. 7A, a padding assembly stackup **700***a* is shown. The padding assembly stackup **700***a* can include a padding layer **702** and an interface layer **704**. The interface layer **704** can be coupled to the padding layer **702**.

[0078] In one embodiment, the padding layer **702** can be formed from an open celled foam. The padding layer **702** can be configured to deform to absorb normal forces, such as **708***a*, applied to the padding layer. In one embodiment, the padding layer **702** can be formed from a single material layer. In other embodiments, the padding layer **702** can be formed from multiple layers of the same or different materials.

[0079] In particular embodiments, the padding layer **702** can be greater than 0 but less than 5 mm thick. In particular embodiments, the padding layer can be between 1 and 3 mm thick. However, a padding layer **702** with a thickness greater than or equal to 5 mm can be utilized.

[0080] In particular embodiment, the padding layer **702** and the interface layer **704** can be formed from a single material. Thus, the interface layer **704** can represent the properties of the padding layer **702** at the interface between the padding layer **702** and the outer shell layer **706**. In another embodiment, the padding layer **702** can be coated, impregnated with a substance or treated in some manner to form the interface layer **704** and change the properties of the padding layer **702** at the outer shell layer interface, such as to reduce friction. In yet another embodiment, the interface layer **704** can be formed from a separate material, which is coupled to the padding layer in some manner, such as adhesively bonded or mechanically attached.

[0081] In one embodiment, the interface layer **704** can be an adhesive which bonds the padding layer **702** to the outer shell. Thus, in response to a tangential force, such as **708***b*, the padding layer **702**, the interface layer **704** and the outer shell layer **706** can move as unit. For example, the padding layer **702**, the interface layer **704** and the outer shell layer **706** can all move to the right in response to tangential force **708***b*, which is to the right.

[0082] In some instances, it can be desirable to limit the amount of tangential force, such as **708***b*, which is transferred through the padding layer **702** and the interface layer **704** to the outer shell layer **706**. Towards this end, the interface layer **704** and the outer shell layer **706** can be configured to help the interface layer **704** to slide relative to the outer shell layer **706** in response to a tangential force, such as **708***b*. For example, the interface layer **704** and the outer shell layer **706** can be formed from smooth materials, such as smooth plastics, where the coefficients of static and sliding friction are relatively low. The low coefficients of friction can allow the two layers **704** and **706** to slide relative to one another when a tangential force, such as **708***b* is applied.

[0083] In one embodiment, the interface layer **704** can be provided as a coating to the padding layer **702**. For example, a bottom surface of a padding layer can be coated with a smooth material, such as a hard plastic. The hard plastic can be flexible or rigid. The smooth material used in the coating can be selected to have both a low coefficient of static and sliding friction. In another embodiment, as described above, the padding layer **702** can be impregnated with a material to improve the coefficient of friction.

[0084] In one embodiment, the material properties of the padding layer **702** can be constant across the layer. In another embodiment, the material properties of the padding layer **702** can be varied. For example, the density of the padding layer **702** can vary across the layer in the normal direction to the surface.

[0085] Next, examples of padding assembly stackups are described where the padding layer and interface layer are configured to allow sliding between the interface layer and the outer shell layer. FIG. 7B illustrates a padding assembly stackup **700***b* in a state where the interface layer **704** has moved relative to the outer shell layer **706**.

[0086] In FIG. 7B, an external force **708** can be applied to the padding layer **702**. The external force includes a normal force component **708***a* and a tangential force component **708***b* component. In response to the normal force component **708***a*, the padding layer **702** can deform to absorb some of the normal force component **708***a*.

[0087] The interface layer **704** is coupled to the padding layer **702** so that the layers can move as a unit. Initially, location **710***b* in the interface layer **704** can be aligned with location **710***a* in the outer shell layer **706**. When the external force **708** is applied, the tangential force component **708***b* can cause the interface layer **704** and padding layer **702** to slide relative to the outer shell layer **706**. A displacement to the right is shown in FIG. 7B.

[0088] The displacement amount is indicated by the distance between location **710***a* in the interface layer **704** and location **710***b* in the outer shell layer **706**. The displacement of interface layer **704** relative to the outer shell layer **706** reduces the shear forces transferred between the layers. As described above, the reduction in the transfer of shear forces can be beneficial for reducing injuries that result from induced rotational motions.

[0089] The amount of displacement of the interface layer **704** relative to the outer shell layer can depend on 1) the magnitude of the tangential force component **708***b*, 2) the magnitude of the normal force component **708***a*, 3) the coefficient of static friction and 4) the coefficient of sliding friction. The force of static friction is proportional to the normal force and the coefficient of static friction. Hence, to cause displacement, the tangential force component **708***b* needs to be large enough to overcome the force of static friction.

[0090] FIG. **7C** illustrates a padding assembly stackup **700***c* where the padding layer is formed as a plurality of pieces. In FIG. 7C, two pieces **716***a* and **716***b* of the padding layer are shown. The two pieces of the padding layer, **716***a* and **716***b*, are coupled to an interface layer **718**, such as adhesively bonded or mechanical attached. The interface layer **718** is continuous and joins the two padding layer pieces together.

[0091] In one embodiment, the interface layer **718** can be formed from a flexible material, such as a piece of cloth or felt. A tangential force, such as **708***b*, can be applied to padding layer piece **716***a*. The tangential force **708***b* can be a component of an external force, such as external force **708** shown in FIG. 7B.

[0092] The tangential force can cause padding layer piece **716***a* to move toward padding layer piece **716***b* and slide relative to outer shell layer **706** while padding layer piece **716***b* initially remains in a fixed position. Thus, location **720***a* in the interface layer can be displaced to the right relative to location **720***b* while locations **722***a* and **722***b* remain static relative to one another. The tangential force can also cause an adjacent piece of the padding layer (not shown) to the left of padding layer piece **716***a* to be pulled along in the same direction.

[0093] When the tangentially force is sufficient, the gap between the pieces can close and pieces **716***a* and **716***b* can contact with one another. When the pieces **716***a* and **716***b* come in contact with one another, in one embodiment, piece **716***b* can be pushed to the right. Thus, location **722***a* in interface layer **718** can be displaced to the right relative to location **722***b* in the outer shell.

[0094] In another embodiment, when the pieces **716***a* and **716***b* into contact with one another, the pieces can bunch up and push each other upwards. Thus, the interface layer **718** can be pulled away from the surface. For example, in response to collision between pieces **716***a* and **716***b*, location **720***a* and location **722***b* can each move away the surface of the outer shell layer **706**.

[0095] A combination of these motions is possible. Hence, piece **716***a* can move to the right and contact piece **716***b*. In response, piece **716***b* can be moved to the right some distance. In addition, a portion of piece **716***b* can be pushed upwards, such that a portion of the interface layer **718** is pushed upwards away from the outer shell layer **706**.

[0096] In FIG. 7D, a padding assembly stackup **700***d* is shown where two padding layer pieces **716***a* and **716***b* are attached to an interface layer **715** formed from an elastic material. In FIG. 7D, a tangential force **708***b* is applied to the second piece **716***b* of the padding layer. The tangential force **708***b* can result from application of an external force, such as external force **708** shown in FIG. 7B. The tangential force **708***b* can cause the padding piece **716***b* to move to the right and relative to the outer shell layer **706**. As an example, prior to the application of the tangential force **708***b*, location **722***a* and location **722***b* can be aligned with one another and then after the application can separate by the amount shown in FIG. 7D.

[0097] As padding layer piece **716***b* moves to the right, depending on the elastic properties of the material of the elastic interface layer **715** and the static friction force holding padding layer piece **716***a* in place, the padding layer **716***a* piece can initially remain static while the elastic interface layer **715** stretches in the gap between the pieces, **716***a* and **716***b*. Hence, the gap between the pieces, **716***a* and **716***b*, can increase.

[0098] Next, after some amount of stretching of the elastic interface layer **715**, piece **716***a* can begin to displace to the right. Since the elastic interface layer **715** can stretch before padding layer piece **716***a* begins to move, the pieces **716***a* and **716***b* can move relative to the outer shell layer **706** by different amounts. Thus, in FIG. 7D, the displacement between locations **722***a* and **722***b* is greater than between locations **720***a* and **720***b*. Similar to above, besides the interface layer **715** sliding relative to the outer shell **706**, the elastic interface layer **715** can also bunch up when pieces, such as **716***a* and **716***b*, contact one another. When the pieces bunch up, the elastic interface layer **715** can be pulled away from the surface at particular locations, such as adjacent to where the pieces contact one another.

[0099] After the elastic interface layer **715** is stretched and the tangential force **708***b* is removed, the energy stored in the elastic interface layer **715** can pull back the pieces of the padding layer, such as **716***a* and **716***b*, towards their original positions. For example, the elastic layer **715** can be anchored (see FIG. **8**C) such that when the tangential force **708***b* is removed, padding layer piece **716***a* and **716***b* can each move to the left. Thus, location **720***b* in the interface layer can move towards location **720***a* in the outer shell layer **706** and location **722***b* in the interface layer **715** can move towards location **722***a* in the outer shell layer **706**.

[0100] Next, with respect to FIG. 7E, a padding assembly stackup **700***e* is described where the padding layer and the interface face layer are both formed in pieces. In FIG. 7E, the padding layer includes two pieces **716***a* and **716***b*. Interface layer pieces **724***a* and **724***b* are associated with the padding layer pieces **716***a* and **716***b*, respectively. A linkage layer **726** is disposed between padding layer and the interface layer.

[0101] The padding layer pieces, **716***a* and **716***b*, and the interface layer pieces, **724***a* and **724***b*, can each be coupled to the linkage layer, such as via an adhesive or mechanical fastener. For example, padding layer piece **716***a* can be bonded to a top surface of the linkage layer **726** and interface layer piece **724***a* is bonded to a bottom surface of the linkage layer directly below the padding layer piece **716***a*. Similarly, padding layer piece **716***b* can be bonded to a top surface of the linkage layer **726** and interface layer piece **724***b* is bonded to a bottom surface of the linkage layer directly below the padding layer piece **716***b*.

[0102] In another embodiment, padding layer **716***a* can be directly coupled to piece **724***a* and padding layer **716***b* can be directly coupled to piece **724***b*. In this embodiment, the linkage layer **726** can be bonded to a top of the padding layer including padding layer pieces **716***a* and **716***b*. For example, a top surface of the padding layer piece **716***a* and a top surface of padding layer piece **716***b* can be coupled to the linkage layer **726**, such as adhesively bonded to a bottom surface of the linkage layer **726**.

[0103] In one embodiment, the linkage layer **726** can be formed from a flexible material but relatively non-elastic material, such as piece of cloth. In another embodiment, the linkage layer **716** can be formed from a mesh, such as a mesh of flexible strings. When one piece in the padding layer is pushed toward another piece, the flexible material can allow the gaps between adjacent pieces to close in a manner that is described above with respect to FIGS. 7C and 7D.

[0104] In yet another embodiment, the linkage layer **726** can be formed from both a flexible and elastic material. In this embodiment, the linkage layer can stretch to allow gaps between the padding layer pieces to increase and to absorb some amount of tangential forces as the interface layer moves relative to the outer shell layer **706**. When the tangential force is removed, the linkage layer **726** can shrink and provide a restoring force which moves the interface layer towards it position relative to the outer shell layer **706** prior to the application of the tangential force.

[0105] Next, with respect to FIGS. **8**A-**8**D padding assemblies for a helmet including attachment schemes for a helmet are described. In FIG. **8**A, a top view of a padding assembly **800** is shown. The padding assembly **800** can be attached over the top of protective gear, such as helmets **201** and **601**, shown in FIGS. **2** and **6** respectively.

[0106] The padding assembly **800** includes a padding layer **802** and an interface layer (not shown). In this example, the padding layer **802** is formed as a single piece. An elastic material **806** is disposed around a perimeter of the padding layer **802**. The elastic material **806** can be used to secure the padding assembly **800** to a helmet.

[0107] The elastic material can include a plurality of attachment points, such as **804***a*, **804***b*, **804***c*, **804***d*, **804***e* and **804***f* The number of attachment points is provided for illustration only and is not meant to be limiting. In other embodiments, a greater number or a lesser number of attachment points can be used.

[0108] In one embodiment, the attachment points can be fasteners, such as rings which go over hooks attached to the protective gear. Alternatively, the attachment points can be hooks which attach to a receiver on the helmet. In another embodiment, the attachment points can be one half of a two piece Velcro system. In general, the attachment points can be one half of a two piece system which can couple the padding assembly **800** to the protective gear.

[0109] In the examples above, the fastener system is configured to allow a padding assembly **800** to be coupled to a protective and then subsequently removed. Thus, the padding assembly **800** can be easily replaced as needed. In other embodiments, the padding assembly can be more permanently bonded to the protective gear. For example, the elastic material **806** can be bonded to a protective gear using an adhesive.

[0110] In operation, in response to a tangential force applied to the padding layer **802**, the padding layer can move relative to the outer shell layer. In response, the elastic material **806** can stretch. The stretching of the elastic material **806** can absorb some of the tangential forces. When the tangential force is removed, the elastic material **806** can shrink and help to restore the padding layer **802** to its initial position.

[0111] The elastic material **806** can be coupled to the padding layer in some manner. In FIG. **8**B, an edge stackup **805** is shown. The edge stackup **805** includes the padding layer **802**, an interface layer **814** disposed between the padding layer **802** and the outer shell layer **812** and the outer shell layer **812** of the helmet. The elastic material **806** is mounted to a top surface of the padding layer **802** around an outer perimeter of the padding layer **802**. In another embodiment, as shown in FIG. **7**E, the elastic material **806** can be disposed between padding layer **802** and the interface layer **814**.

[0112] Next, with respect to FIG. **8**E, a second example of padding assembly **810**, which can be secured to a protective gear, is shown. In **810**, the padding is formed as a plurality of pieces **802***a*, **802***b*, **802***c*, **802***d*, **802***e* and **802***f* An elastic material **806** is disposed around and extends from the edges of the padding pieces. Attachment points **804***a*, **804***b*, **804***c*, **804***d*, **804***e* and **804***f* can be used to secure the padding assembly to the protective gear.

[0113] In one embodiment, the elastic material **806** can extend of the top of each of the padding pieces. The padding pieces can each be secured to the elastic material **806** and the elastic material can hold the padding pieces in place. In another embodiment (see FIG. **7**E), the elastic material **806** can form a linkage layer disposed between an interface layer and the padding pieces. In yet another embodiment (see FIG. **7**D), the elastic material **806** can form the interface layer between the padding pieces and the outer shell layer of the helmet.

[0114] In FIG. **8**D, a padding assembly **820** for protective gear, such as a helmet is shown. The padding assembly includes padding **802** and a plurality of flexures **822***a*, **822***b*, **822***c* and **822***d*. The flexures **822***a*, **822***b*, **822***c* and **822***d* are coupled to the padding **802**, such as via attachment points. For example, flexure **822***a* is secured to the padding layer via fasteners **824***a* and **824***b*.

[0115] The flexures **822***a*, **822***b*, **822***c* and **822***d* can be configured to be attached to the helmet. For example, flexures can be configured to slip around hooks attached to the helmet. In one embodiment, the flexures can be formed from an elastic material. Thus, the flexure can be stretched to secure it to the helmet. When a tangential force hits the padding, the flexures can stretch to absorb some of the tangential forces. When the tangential force is removed, the flexures can shrink to restore the padding layer to a more centered position over the helmet.

[0116] Although the foregoing invention has been described in some detail for purposes of clarity of understanding, it will be apparent that certain changes and modifications may be practiced within the scope of the appended claims. Therefore, the present embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalents of the appended claims.

What is claimed is:

1. A helmet comprising:

a first shell layer;

a second shell layer connected to the first shell layer through a first energy transformer layer, the first energy transformer layer operable to absorb energy from forces imparted onto the first shell layer, wherein the first energy transformer layer includes an absorptive/dissipative a material to allow the first shell layer to slide relative to the second shell layer; and

a padding assembly, disposed above the first shell layer, including a padding layer and an interface layer which contacts the first shell layer.

2. The helmet of claim **1**, wherein the padding layer is formed from an open-celled foam.

3. The helmet of claim **1**, wherein the padding layer is between 1 to 5 mm thick.

4. The helmet of claim **1**, wherein the interface layer is an adhesive which bonds the padding layer to the first shell layer.

5. The helmet of claim **1**, wherein the interface layer which contacts the first shell layer and is configured to slide relative to an outer surface of the first shell layer in response to tangential forces applied to the padding assembly.

6. The helmet of claim **1**, further comprising a lining layer connected to the second shell layer, wherein the lining layer is configured to conform to a human head.

7. A helmet comprising:

a first shell layer;

a second shell layer connected the first shell layer through a first energy transformer layer, the first energy transformer layer operable to absorb energy from forces imparted onto the first shell layer, wherein the first energy transformer layer includes an absorptive/dissipative a material to allow the first shell layer to slide relative to the second shell layer; and

a padding assembly, disposed above the first shell layer, including a padding layer coupled to an interface layer wherein the interface layer contacts the first shell layer and is configured to slide relative to an outer surface of the first shell layer in response to tangential forces applied to the padding layer.

8. The helmet of claim **7**, wherein the padding layer is formed from an open-celled foam.

9. The helmet of claim **7**, wherein the padding layer is between 1 to 5 mm thick.

10. The helmet of claim **7**, wherein the interface layer is formed from a hard plastic material.

11. The helmet of claim **7**, wherein a coating is added to the padding layer to form the interface layer.

12. The helmet of claim **7**, wherein the interface layer is bonded to the padding layer.

13. The helmet of claim **7**, wherein the padding layer is formed from a plurality of pieces.

14. The helmet of claim **13**, wherein the plurality of pieces are bonded to a contiguous interface layer.

15. The helmet of claim **13**, wherein the interface layer is formed from an elastic material which allows gaps between the plurality of pieces to dynamically increase in response to the application of the tangential forces and to dynamically decrease when the tangential forces are removed.

16. The helmet of claim **7**, wherein the padding assembly is formed from a plurality of pieces each of the plurality of pieces including the padding layer and the interface layer.

17. The helmet of claim **16**, further comprising linkages separate from the padding layer and the interface layer which couple the plurality of pieces to one another.

18. The helmet of claim **17**, wherein the linkages are formed from an elastic material which, in response to the application of the tangential forces, is configured to stretch to store energy and allow gaps between the plurality of pieces to dynamically increase and which, in response to a removal of the tangential forces, is configured to shrink, to release energy and cause the gaps between the plurality of pieces to dynamically decrease.

19. The helmet of claim **7**, further comprising a plurality of members attached to the padding assembly around an outer perimeter of the padding assembly wherein the members secure the padding assembly to the helmet.

20. The helmet of claim **19**, wherein the plurality of members are formed from an elastic material which, in response to the application of the tangential forces, is configured to stretch to store energy while allowing the padding assembly to move relative to the first shell from a first position to a second position and which, in response to the removal of the tangential forces, is configured to shrink, to release energy and return the padding assembly from the second position towards the first position.

21. The helmet of claim **7**, further comprising an elastic mesh including a plurality of attachment points extending from an outer perimeter of the padding assembly wherein the attachment points secure the padding assembly to the helmet.

22. The helmet of claim **21**, wherein the elastic mesh, in response to the application of the tangential forces, is configured to stretch to store energy while allowing the padding assembly to move relative to the first shell from a first position to a second position and, in response to the removal of the tangential forces, is configured to shrink, to release energy and return the padding assembly from the second position towards the first position.

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