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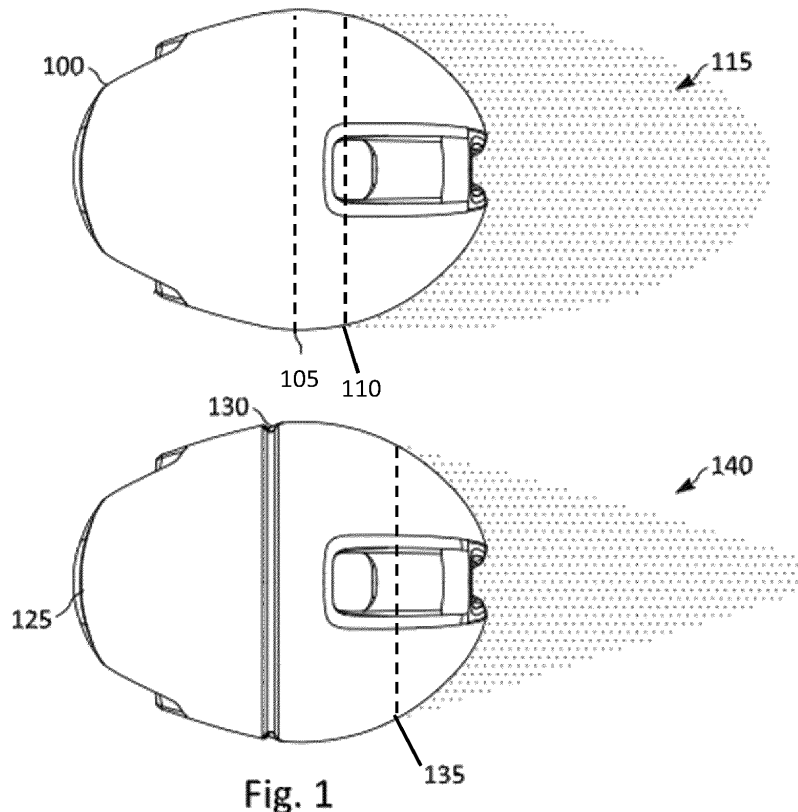
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(54) **HELMET WITH AN AIR TRIP**

(57) A helmet 125 includes an energy absorbing layer and an outer shell mounted to the energy absorbing layer. The outer shell includes an air trip 130 in the form of a continuous groove that extends from a bottom left side of the helmet to a bottom right side of the helmet.



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Description

BACKGROUND

[0001] A cycling helmet is often worn by bicyclists as a safety precaution to help prevent injury in the event of a cycling accident. Traditional cycling helmets come in a large variety of different shapes and can be composed of numerous different materials, and these characteristics can have a large effect on the overall aerodynamics of the helmet. In addition to the bicycle itself and the cyclist's body/clothing, the cycling helmet used also contributes to the air resistance that results from riding the bicycle. As a result, many modern helmets are designed to have aerodynamic shapes that are intended to result in reduced air resistance when worn during cycling. The reduced air resistance results in increased cycling speed and an overall more comfortable cycling experience.

SUMMARY

[0002] An illustrative helmet includes an energy absorbing layer and an outer shell mounted to the energy absorbing layer. The outer shell of the helmet includes an air trip in the form of a continuous groove that extends from a bottom left side of the helmet to a bottom right side of the helmet. In an illustrative embodiment, the continuous groove has a u-shaped cross-section. In another embodiment, the helmet includes a front and a back, and the air trip is positioned closer to the front of the outer shell than a position of a natural laminar-to-turbulent airflow transition region of the outer shell.

[0003] In another embodiment, the air trip has a first curved transition that transitions from the outer shell into a front portion of the air trip, and a second curved transition that transitions from the outer shell into a back portion of the air trip. In some embodiments, the first curved transition has a first radius of curvature that differs from a second radius of curvature of a bottom of the groove. In another embodiment, the first curved transition has a first radius of curvature and the second curved transition has a second radius of curvature, where the first radius of curvature is the same as the second radius of curvature. In another embodiment, the air trip is at an angle of 90 degrees relative to an outer surface of the outer shell of the helmet. Alternatively, the air trip can be at an angle of greater than or less than 90 degrees relative to the outer shell of the helmet. In another illustrative embodiment, a thickness of the outer shell is constant over the entire outer shell, including at the air trip.

[0004] An illustrative method of making a helmet includes forming an outer shell with an air trip, where the air trip comprises a continuous groove that extends from a bottom left side of the outer shell to a bottom right side of the outer shell. The method also includes forming an energy absorbing layer that includes an energy absorbing layer groove that is configured to receive the air trip. The method further includes mounting the energy ab-

sorbing layer to the outer shell. In one embodiment, forming the air trip comprises forming the continuous groove to have a u-shaped cross section.

[0005] The method can also include determining a location on the outer shell of a natural laminar-to-turbulent airflow transition region. In such an embodiment, forming the air trip comprises positioning the air trip at a location on the outer shell that is closer to a front of the helmet than the natural laminar-to-turbulent airflow transition region. In another embodiment, forming the air trip includes forming a first curved transition that transitions from the outer shell into a front portion of the air trip and forming a second curved transition that transitions from the outer shell into a back portion of the air trip. In one embodiment, the first curved transition is formed with a first radius of curvature and a bottom of the groove is formed with a second radius of curvature that differs from the first radius of curvature. In another embodiment, the first curved transition is formed to have a first radius of curvature and the second curved transition is formed to have a second radius of curvature, where the first radius of curvature is the same as the second radius of curvature.

[0006] In yet another embodiment, forming the air trip includes positioning the air trip at an angle of 90 degrees relative to an outer surface of the outer shell of the helmet. Alternatively, forming the air trip can include positioning the air trip at an angle of less than or greater than 90 degrees relative to an outer surface of the outer shell of the helmet. The method can further include forming the outer shell such that a thickness of the outer shell is constant over the entire outer shell, including at the air trip.

[0007] Other principal features and advantages of the invention will become apparent to those skilled in the art upon review of the following drawings, the detailed description, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Illustrative embodiments will hereafter be described with reference to the accompanying drawings, wherein like numerals denote like elements. The foregoing and other features of the present disclosure will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only several embodiments in accordance with the disclosure and are, therefore, not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through use of the accompanying drawings.

Fig. 1 depicts results of a helmet air trip resistance test conducted to validate the air trip concept in accordance with an illustrative embodiment.

Fig. 2A is a plan view of a helmet with an air trip in accordance with an illustrative embodiment.

Fig. 2B is a rear view of the helmet in accordance with an illustrative embodiment.

Fig. 2C is a bottom (or interior) view of the helmet in accordance with an illustrative embodiment.

Fig. 2D is a side view of the helmet in accordance with an illustrative embodiment.

Fig. 2E is a bottom right side perspective view of the helmet in accordance with an illustrative embodiment.

Fig. 2F is a bottom left side perspective view of the helmet in accordance with an illustrative embodiment.

Fig. 2G is a bottom rear perspective view of helmet showing a center line A in accordance with an illustrative embodiment.

Fig. 2H is a cross-sectional view of the helmet along the center line A of Fig. 2G in accordance with an illustrative embodiment.

Fig. 3A is a close-up cross-sectional view of the air trip in accordance with an illustrative embodiment.

Fig. 3B depicts a configuration in which the air trip angle is less than 90 degrees in accordance with an illustrative embodiment.

Fig. 3C depicts a configuration in which the air trip angle is greater than 90 degrees in accordance with an illustrative embodiment.

Fig. 4 is a flow diagram depicting operations performed to make a helmet with an air trip in accordance with an illustrative embodiment.

DETAILED DESCRIPTION

[0009] The speed at which a bicycle travels depends on a large number of variables, including the type of bicycle frame, the type of tires mounted to the bicycle frame, the air pressure in the tires, the size of the rider, the environment in which the bicycle is being ridden, the weather, the amount of effort put into pedaling, etc. Another factor that can significantly impact cycling speed is air resistance. Air resistance results from contact between air in the ambient environment and the combined volume of the rider, bicycle, clothing, etc. as the rider propels the bicycle within the environment. An oncoming wind can increase the amount of air resistance experienced by the rider.

[0010] A considerable amount of air resistance can result from the rider's helmet, since a significant portion of the helmet can be in contact with the oncoming air as the

rider pedals the bicycle. It has been shown that even helmets with an aerodynamic shape can have considerable air resistance at high speeds. Described herein is a helmet that includes an air trip (or turbulator) that is used to significantly reduce the effect of air resistance on the helmet. As described in more detail below, the air trip is a continuous groove formed in an outer shell of the helmet such that the groove is perpendicular to the airflow direction as the helmet wearer rides the bicycle. In an illustrative embodiment, the air trip runs from a bottom of a first (left) side of the helmet to a bottom of a second (right) side of the helmet. The air trip operates by moving a laminar-to-turbulent airflow transition point of the oncoming air such that the generated turbulent air flow has a significantly lesser resistive effect on the helmet. This principle is described in more detail with reference to Fig. 1.

[0011] Fig. 1 depicts results of a helmet air trip resistance test conducted to validate the air trip concept in accordance with an illustrative embodiment. Specifically, the upper portion of Fig. 1 depicts the effects of oncoming air contacting a smooth helmet 100, which does not include an air trip. In the actual tests, the oncoming air (referred to as air or airflow for simplicity) was actually a smoke/air gas mixture that was used so that the gaseous response could be visualized. Additionally, the test was conducted in an air tunnel such that a rate of the oncoming airflow could be precisely controlled. The smooth helmet 100 is shown as a top view that depicts the dome (top) portion of the outer shell of the helmet. The oncoming airflow is generally laminar prior to contacting the smooth helmet 100. After contacting the smooth helmet 100, the airflow reaches a transition region 105 on the smooth helmet 100 at which the air transitions from a laminar flow to a turbulent flow. The transition region 105 (shown via a dashed line) is essentially a continuous region that runs in a ring about a perimeter of the smooth helmet 100. As shown, the transition region 105 is at or slightly forward of the center of the smooth helmet 100. The turbulent airflow generated at the transition region 105 separates from the smooth helmet 100 at a separation region 110 (also shown with a dashed line), which is located to the rear (i.e., with the initial point of contact of the airflow and the smooth helmet 100 being forward) of the transition region 105. Similar to the transition region 105, the separation region 110 is also a continuous region that runs in a ring about a perimeter of the smooth helmet 100. The upper portion of Fig. 1 also depicts a wake 115 generated by the turbulent air flow that separated from the smooth helmet 100. As shown, the generated wake 115 is larger than a diameter of the smooth helmet 100. Such a large wake creates significant drag, which in the context of a cycling helmet, can significantly reduce the speed of the rider.

[0012] The lower portion of Fig. 1 depicts an air trip helmet 125 of the same general size/shape/mass/etc. as the smooth helmet 100. However, the air trip helmet 125 includes an air trip 130 out an outer surface thereof. The

air trip 130 is a continuous groove that runs in a ring about a perimeter of the air trip helmet 125. The air trip 130 is positioned at an angle relative to an outer surface of the air trip helmet 125 such that it is perpendicular to the airflow. By perpendicular, it is meant that a line perpendicular to and extending outward from a center of the bottom of the groove (that forms the air trip 130) is perpendicular to the airflow. The air trip 130 is located forward of the previously identified natural transition region 105 such that the air trip 130 is closer to the initial point of contact between the airflow and the air trip helmet 125 than is the natural transition region of the air trip helmet 125. As a result, the oncoming air is tripped (i.e., caused to transition from laminar flow to turbulent flow) earlier than it otherwise would have been. Being caused to transition at this more forward location causes a more rearward separation region 135 (shown via dashed line) for the air trip helmet 125, as compared to the smooth helmet 100 depicted in the upper portion of Fig. 1. The more rearward separation region 135 results in a wake 140 that is significantly smaller than the wake generated by the smooth helmet 100. As a result, the air trip helmet 125 has significantly less drag than the smooth helmet 100, which in the context of a cycling helmet can increase the rider speed and result in a more comfortable experience.

[0013] In terms of aerodynamics, the use of the proposed air trip to transition (or move) the laminar-to-turbulent flow transition point forward of the normal transition region acts to add energy to the airflow. While it might seem that this added energy would cause a larger, more turbulent wake, it was found that the opposite is the case. Through experimentation in the wind tunnel, it was determined that the aforementioned energy added to the turbulent airflow causes the airflow to stay attached to the object (i.e., helmet) further back than it otherwise would have done. In other words, the added energy resulting from moving the transition point forward causes the flow separation to occur further back on the helmet. By remaining attached to the object for a longer time, the airflow releases toward the rear of the object (i.e., as opposed to forward of the middle of the object), resulting in a much smaller wake.

[0014] The tests referenced above with respect to Fig. 1 were conducted in a wind tunnel, and numerous different shapes, sizes, angles, locations, etc. of the air trip were tested to identify an optimal configuration for the air trip. In addition to the testing discussed above with respect to Fig. 1, to develop the proposed helmet multiple rounds of Computational Fluid Dynamics (CFD) and Wind Tunnel Testing were conducted to compare different air trip designs along with the helmet shape, vent placement and shapes, and numerous other design variables. Throughout the testing, the air trip design was optimized for shape, size, and location on the helmet.

[0015] Specifically, through various types of experimentation, including trial-and-error, the inventors determined that placing the air trip forward of the natural tran-

sition point of the helmet resulted in the greatest reduction in wake. The inventors also determined through experimentation that a shelf or ledge (i.e., drop off) formed in the outer shell of the helmet does not provide anywhere near the same level of wake reduction as the proposed air trip in the form of a continuous groove. The reason for this is that a shelf/ledge does not cause the laminar airflow to transition from laminar flow to turbulent flow at a location that is forward of the normal/natural laminar-to-turbulent transition region. In other words, a shelf/ledge does appear to move the laminar-to-turbulent transition region (on the helmet) of the airflow forward, and therefore does not significantly decrease wake or drag. Similarly, through experimentation, the inventors determined that an air trip that does not fully extend from the bottom of the first side of the helmet to the bottom of the second side of the helmet is much less effective. The inventors also determined through experimentation that an air vent or other through hole in the helmet does not have the same effect as the proposed air trip because such vents/holes do not alter laminar-to-turbulent transition region of the helmet in a way that decreases wake.

[0016] Figs. 2A-2H depict various views of a helmet 200 with an air trip 205 to provide reduced wake and drag, and increased speed. Specifically, Fig. 2A is a plan view of the helmet with the air trip 205 in accordance with an illustrative embodiment. Fig. 2B is a rear view of the helmet 200 in accordance with an illustrative embodiment. Fig. 2C is a bottom (or interior) view of the helmet 200 in accordance with an illustrative embodiment. Fig. 2D is a side view of the helmet 200 in accordance with an illustrative embodiment. Fig. 2E is a bottom right side perspective view of the helmet 200 in accordance with an illustrative embodiment. Fig. 2F is a bottom left side perspective view of the helmet 200 in accordance with an illustrative embodiment. Fig. 2G is a bottom rear perspective view of helmet 200 showing a center line A in accordance with an illustrative embodiment. Fig. 2H is a cross-sectional view of the helmet 200 along the center line A of Fig. 2G in accordance with an illustrative embodiment.

[0017] As discussed above, the air trip 205 makes the helmet 200 more aerodynamic to help the rider go faster. The air trip 205 is a groove recessed into the helmet 200. The air trip 205 is located just in front of where the air would normally transition from laminar to turbulent flow (i.e., in front of the normal or natural laminar-to-turbulent airflow transition region of the helmet). Additionally, the air trip 205 is positioned perpendicular to the airflow direction. The air trip 205 works as a boundary layer control device to force the air to transition from laminar flow to turbulent flow at the groove. This transition adds energy to the air flow, allowing the air flow to stay attached further back on the helmet and reducing the size of the wake. This in turn reduces the amount of drag that the helmet creates, making it faster. The air trip 205 also makes the helmet 200 more aerodynamic in different rider positions and different rider speeds. In an illustrative embodiment,

the air trip 205 can be designed to provide the greatest reduction of drag at a speed of 26 miles per hour (mph). Alternatively, the air trip 205 may be designed to provide the greatest reduction of drag at a different speed, such as 20 mph, 22 mph, 24 mph, 28 mph, etc.

[0018] As shown, the air trip 205 is formed in an outer shell 210 of the helmet 200. The outer shell 210 of the helmet 200 can be made from plastic, resin, fiber, polycarbonate, polyethylene, terephthalate (PET), acrylonitrile butadiene styrene, polyethylene (PE), polyvinyl chloride (PVC), vinyl nitrile (VN), fiberglass, carbon fiber, or other similar material. In addition to housing other components of the helmet 200, the outer shell 210 provides a rigid outer layer. Depending on the implementation, the outer shell 210 can be formed through stamping, molding, vacuum forming, or any other known fabrication technique. Mounted to the outer shell 210 is an energy absorbing layer 215. The energy absorbing layer 215 can be formed from a closed cell foam such as expanded polystyrene (EPS) in one embodiment. In another embodiment, the energy absorbing layer 215 can be formed from an energy absorbing layer with multi-directional flexibility. Such an energy absorbing material, which can be made from polycarbonate or a similar material, is able to bend, compress, stretch, and shift in multiple directions without shearing. In one embodiment, the energy absorbing layer 215 can be formed in part by a closed cell foam layer and in part by one or more energy absorbing inserts that are supported by the closed cell foam layer. The energy absorbing layer 215 can be mounted to the outer shell 210 via an adhesive, through co-molding, etc.

[0019] In one embodiment, the energy absorbing layer 215 includes one or more embedded mounts (e.g., mushroom plugs, threaded openings, clips, etc.) that are used to secure a fit system to the helmet 200. In an illustrative embodiment, the fit system can include a yoke and straps for securing the helmet 200 to a user's head. The helmet 200 also includes vents 220 that are used to assist with ventilation and rider comfort. As shown, the vents 220 are formed in the outer shell 210 of the helmet at locations positioned to the rear of the air trip 205. As best depicted in Fig. 2B, the vents 220 formed in the helmet 200 include a vent positioned on the top center of the helmet 200, a vent positioned on the back center of the helmet 200, a vent positioned on the back left of the helmet 200, and a vent positioned on the back right of the helmet 200. In alternative embodiments, fewer or additional vents may be used, and the vent(s) may be positioned at different locations on the helmet 200.

[0020] In the cross-sectional view of Fig. 2H, it can be seen that the air trip 205 has a (curved) u-shaped cross-section. In alternative embodiments, a different shape may be used for the cross-section of the groove, such that the groove has a v-shaped cross-section, a partial (i.e., three-sided) square-shaped cross-section, a partial (i.e., three-sided) rectangle-shaped cross-section, etc. Fig. 3A is a close-up cross-sectional view of the air trip in accordance with an illustrative embodiment. While Fig.

3A includes example dimensions (in millimeters) that were determined to be optimal through experimentation and testing, it is to be understood that different dimensions may be used for the air trip in alternative embodiments.

[0021] As shown in Fig. 3A, the air trip has a u-shaped cross-section with a curved bottom that flattens out at its center, a first curved transition 315 from a front portion of the helmet to the air trip, and a second curved transition 320 from a rear portion of the helmet to the air trip. An example radius of curvature of the curved bottom of the air trip can be 2.5 mm. Also, a radius of curvature of the first curved transition 315 and the second curved transition 320 can be 2.25 mm. In alternative embodiments, different radii of curvature may be used. For example, all 3 radii of curvature may be the same, at 2.25 mm, 2.5 mm, or a different value such as 1.5 mm, 2 mm, 2.75 mm, 3 mm, 3.5 mm, etc. In one embodiment, the first curved transition 315 can have a radius of curvature that differs from that of the second curved transition 320. As also shown, a depth of the groove that forms the air trip can be 4.5 mm in one embodiment, and an inner width of the groove can be 5 mm. Additionally, an outer width between the start of the first curved transition 315 and the start of the second curved transition 320 can be 10.2 mm. In alternative embodiments, different depths (e.g., 3.5 mm, 3.75 mm, 4 mm, 4.75 mm, 5.5 mm, etc.), inner widths (e.g., 4 mm, 4.5 mm, 5.5 mm, 6 mm, etc.), and/or outer widths (e.g., 9 mm, 9.5 mm, 10.5 mm, 11 mm, 12 mm, etc.) may be used.

[0022] As also shown in Fig. 3A, the groove that forms the air trip is positioned at an angle relative to an exterior surface of the outer shell. The angle at which the air trip is positioned can be based at least in part on rider style, and different helmets can have air trips positioned at different angles to accommodate different riders. In an illustrative embodiment, the angle of the air trip is controlled such that the air trip is perpendicular to oncoming air while the rider is in position to operate the bicycle. The angle of the air trip can be conceptualized by initially considering a tangent line 300 that is tangent to a bottom of the center of the air trip and a line 305 that extends perpendicular to the tangent line and that includes the center of the bottom of the air trip. These lines are depicted in Fig. 3A, and remain perpendicular to one another regardless of the angle of the air trip. The line 305 intersects a line 310 that extends along the outer surface of the outer shell from a start of the first curved transition 315 of the air trip to a start of the second curved transition 320 of the air trip. In the embodiment shown, the angle between the line 305 and the line 310 is 90 degrees, which means that the air trip has an angle of 90 degrees relative to the outer surface of the outer shell.

[0023] To accommodate different rider styles and/or helmet shapes, the angle of the air trip can be altered to ensure that the oncoming air contacts the air trip in a perpendicular manner. For example, the air trip can be positioned at an angle such that the tangent line 300 and

the line 305 (perpendicular to the tangent line) from Fig. 3A are both rotated in a counterclockwise direction such that the air trip angle θ (i.e., the angle between the line 305 and the line 310) is less than 90 degrees. Fig. 3B depicts a configuration in which the air trip angle is less than 90 degrees in accordance with an illustrative embodiment. In such an embodiment, the air trip angle θ can be 70 degrees, 75 degrees, 80 degrees, 85 degrees, etc.

[0024] Similarly, the air trip can be positioned such that the tangent line 300 and the line 305 (perpendicular to the tangent line) from Fig. 3A are both rotated in a clockwise direction such that the air trip angle θ (i.e., the angle between the line 305 and the line 310) is greater than 90 degrees. Fig. 3C depicts a configuration in which the air trip angle is greater than 90 degrees in accordance with an illustrative embodiment. In such an embodiment, the air trip angle θ can be 95 degrees, 100 degrees, 110 degrees, 115 degrees, etc.

[0025] Fig. 4 is a flow diagram depicting operations performed to make a helmet with an air trip in accordance with an illustrative embodiment. In alternative embodiments, fewer, additional, and/or different operations may be performed. Also, the use of a flow diagram is not meant to be limiting with respect to the order of operations performed. In an operation 400, a computing device is used to determine parameters for an air trip to be used on a helmet. The computing device can include a processor, a memory, a user interface (e.g., mouse, keyboard, display) to receive user commands and present results, a transceiver (e.g., receiver and transmitter) for communication with remote devices and systems, etc. The memory can be used to store computer-readable instructions that act to execute any of the design, testing, and analysis operations described herein. The processor can execute the computer-readable instructions to implement the operations.

[0026] The parameters for the air determined by the computer can include a location of the air trip on the helmet (which can be determined based on an identified location of the natural laminar-to-turbulent airflow transition region on the helmet), an inner width of the air trip, an outer width of the air trip, a depth of the air trip, a radius of curvature of a curved bottom of the air trip, a radius of curvature of a first curved transition of the air trip, a radius of curvature of a second curved transition of the air trip, etc. The parameters can also include an angle of the air trip, as discussed herein. The parameters can be determined through computational fluid dynamic analyses, wind tunnel testing, trial-and-error testing, etc. The parameters can be based on helmet shape, a determined riding/head position for a given cyclist (or for a group of cyclists that all ride in similar positions), the type of bicycle with which the helmet is intended to be used, a desired riding speed, etc.

[0027] In an operation 405, an outer shell for the helmet is formed with the air trip, based on the determined parameters for the air trip. In an illustrative embodiment,

the outer shell is formed via molding, and the air trip is molded into the outer shell as a continuous groove that extends from a bottom left side of the helmet to a bottom right side of the helmet. As discussed, the air trip is positioned on the helmet forward of a natural laminar-to-turbulent flow transition region of the helmet. In another illustrative embodiment, a thickness of the outer shell remains the same over the entire outer shell, including at the air trip. In another embodiment, the outer shell may not be used, and the helmet can be formed using just the energy absorbing layer with the air trip formed in the energy absorbing layer.

[0028] In an operation 410, an energy absorbing layer for the helmet is formed such that the energy absorbing layer includes a groove to accommodate the air trip. As such, the groove in the energy absorbing layer receives the air trip such that the energy absorbing layer and outer shell can be tightly secured to one another. The energy absorbing layer can be formed from molding, or using any other technique known in the art. As discussed, the energy absorbing layer can include one or more embedded mounts (mushroom plugs, clips, etc.) that can be used to secure items (e.g., a fit system) to the helmet. The energy absorbing layer can also include multiple materials in some embodiments, such as a closed cell foam layer that surrounds inserts of energy absorbing material. In an operation 415, the energy absorbing layer is mounted to the outer shell. The mounting can be performed using an adhesive, or any other technique. In an operation 420, a fit system is mounted to the helmet such that the helmet can be secured to the rider's head. The fit system can be mounted by attaching it to the mounts embedded in the energy absorbing layer.

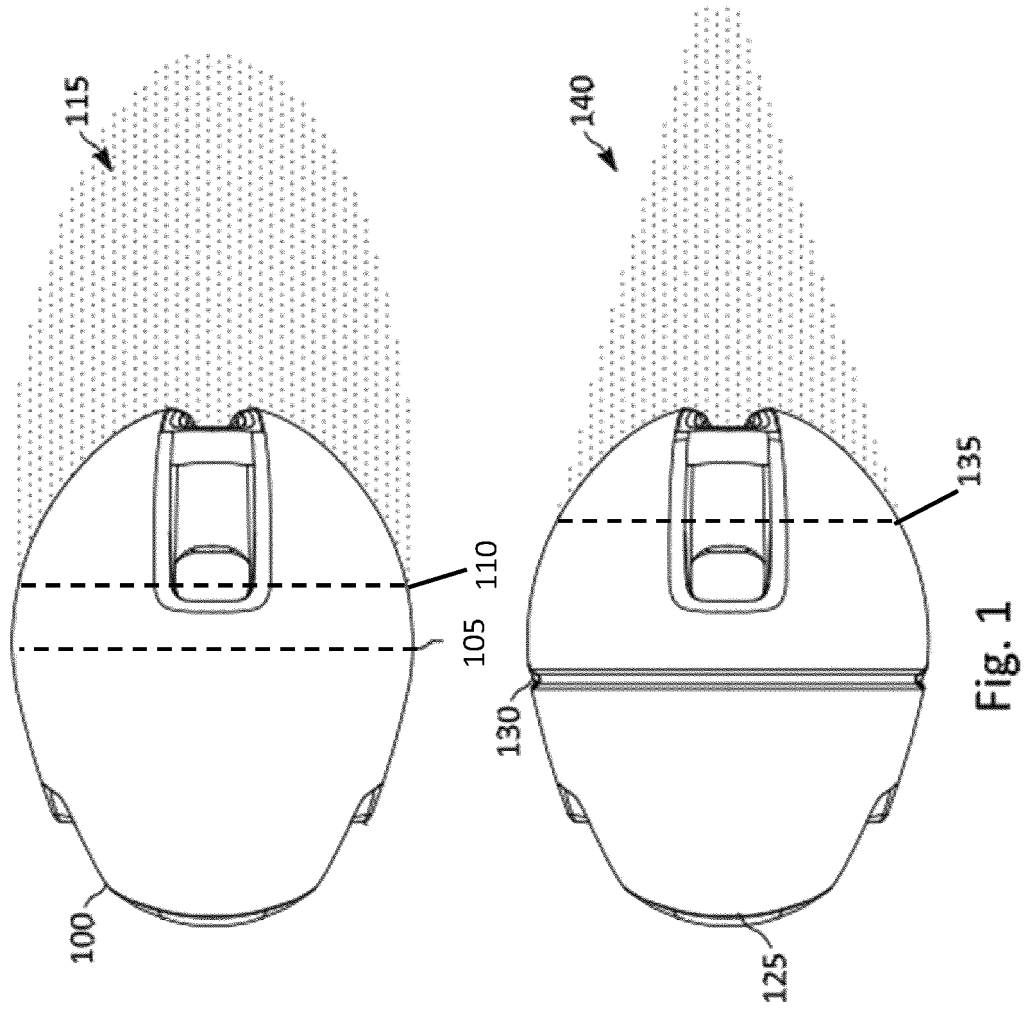
[0029] The word "illustrative" is used herein to mean serving as an example, instance, or illustration. Any aspect or design described herein as "illustrative" is not necessarily to be construed as preferred or advantageous over other aspects or designs. Further, for the purposes of this disclosure and unless otherwise specified, "a" or "an" means "one or more".

[0030] The foregoing description of illustrative embodiments of the invention has been presented for purposes of illustration and of description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and modifications and variations are possible in light of the above teachings or may be acquired from practice of the invention. The embodiments were chosen and described in order to explain the principles of the invention and as practical applications of the invention to enable one skilled in the art to utilize the invention in various embodiments and with various modifications as suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto.

Claims

- 1. A helmet comprising:
 - an energy absorbing layer; and
 - an outer shell mounted to the energy absorbing layer, wherein the outer shell includes an air trip in the form of a continuous groove that extends from a bottom left side of the helmet to a bottom right side of the helmet.
- 2. The helmet of claim 1, wherein the continuous groove has a u-shaped cross-section.
- 3. The helmet of claim 1 or 2, wherein the helmet includes a front and a back, and wherein the air trip is positioned closer to the front of the outer shell than a position of a natural laminar-to-turbulent airflow transition region of the outer shell.
- 4. The helmet of any preceding claim, wherein the air trip has a first curved transition that transitions from the outer shell into a front portion of the air trip.
- 5. The helmet of claim 4, wherein the air trip has a second curved transition that transitions from the outer shell into a back portion of the air trip.
- 6. The helmet of claim 4, wherein the first curved transition has a first radius of curvature that differs from a second radius of curvature of a bottom of the groove.
- 7. The helmet of claim 5, wherein the first curved transition has a first radius of curvature and the second curved transition has a second radius of curvature, and wherein the first radius of curvature is the same as the second radius of curvature.
- 8. The helmet of any preceding claim, wherein a thickness of the outer shell is constant over the entire outer shell, including at the air trip.
- 9. A method of making a helmet, the method comprising:
 - forming an outer shell with an air trip, wherein the air trip comprises a continuous groove that extends from a bottom left side of the outer shell to a bottom right side of the outer shell;
 - forming an energy absorbing layer that includes an energy absorbing layer groove that is configured to receive the air trip; and
 - mounting the energy absorbing layer to the outer shell.
- 10. The method of claim 9, further comprising determining a location on the outer shell of a natural laminar-

- to-turbulent airflow transition region.
- 11. The method of claim 10, wherein forming the air trip comprises positioning the air trip at a location on the outer shell that is closer to a front of the helmet than the natural laminar-to-turbulent airflow transition region.
- 12. The method of any of claims 9 to 11, wherein forming the air trip includes forming a first curved transition that transitions from the outer shell into a front portion of the air trip and forming a second curved transition that transitions from the outer shell into a back portion of the air trip.
- 13. The method of claim 12, wherein the first curved transition is formed with a first radius of curvature and a bottom of the groove is formed with a second radius of curvature that differs from the first radius of curvature.
- 14. The method of claim 12, wherein the first curved transition is formed to have a first radius of curvature and the second curved transition is formed to have a second radius of curvature, and wherein the first radius of curvature is the same as the second radius of curvature.
- 15. The method of any of claims 9 to 14, further comprising forming the outer shell such that a thickness of the outer shell is constant over the entire outer shell, including at the air trip.



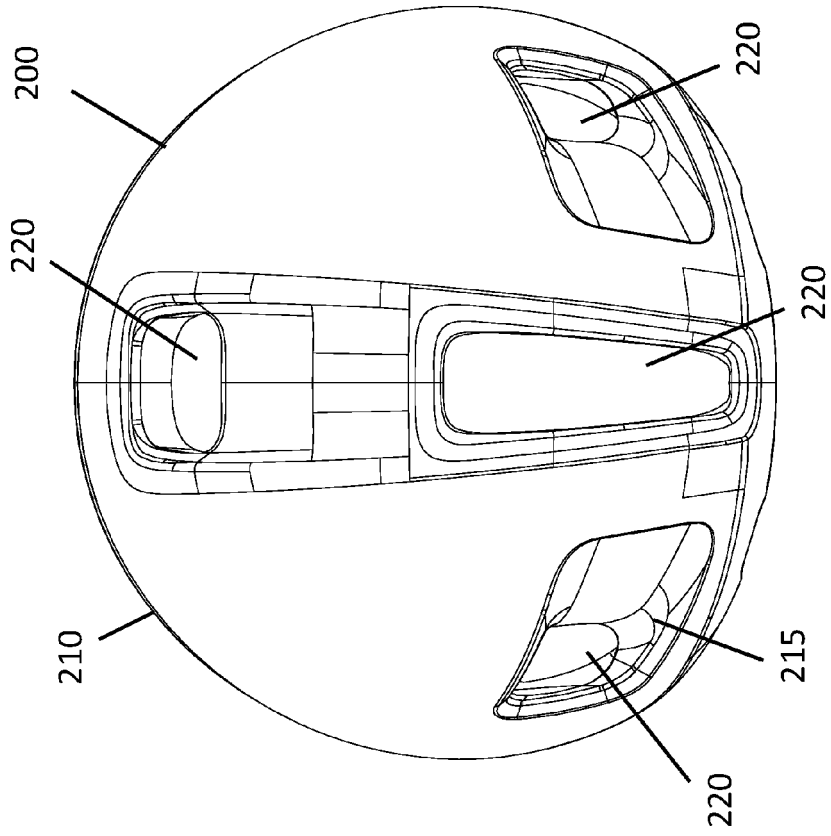


Fig. 2B

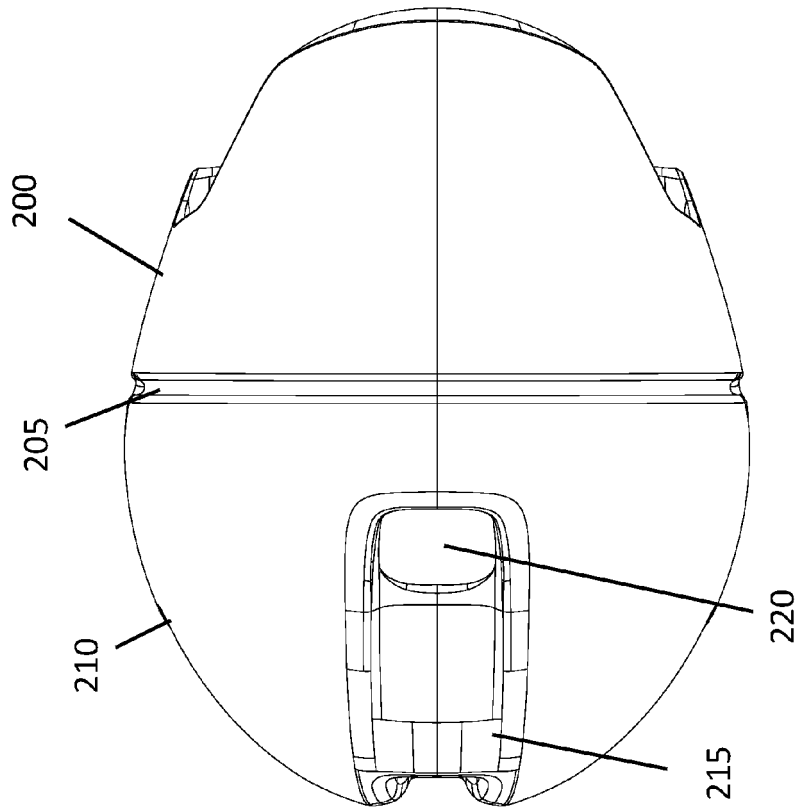


Fig. 2A

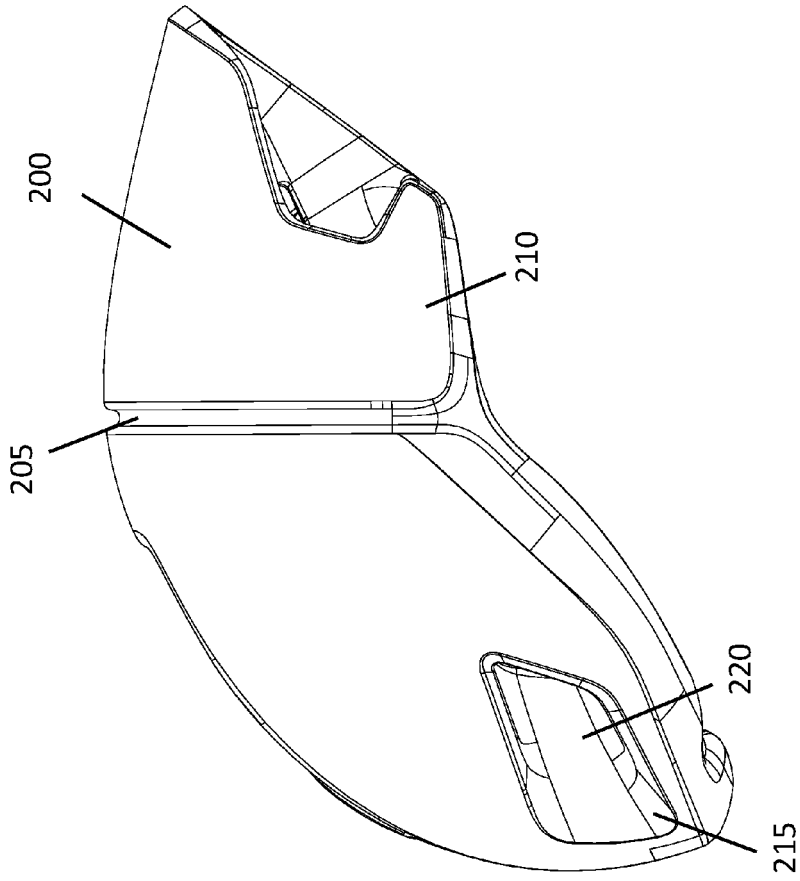


Fig. 2D

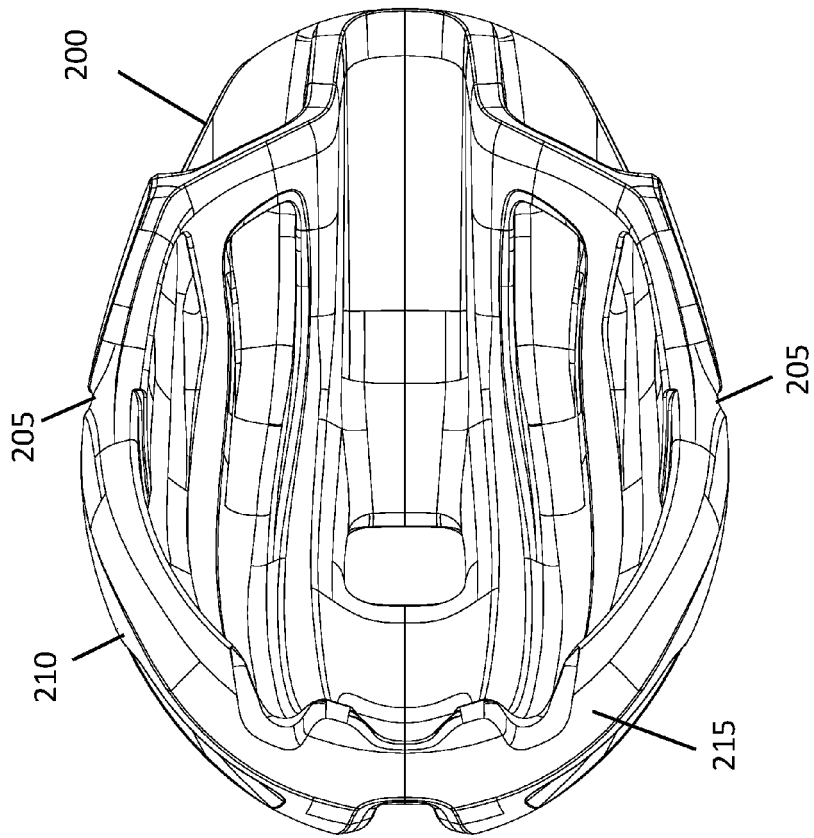


Fig. 2C

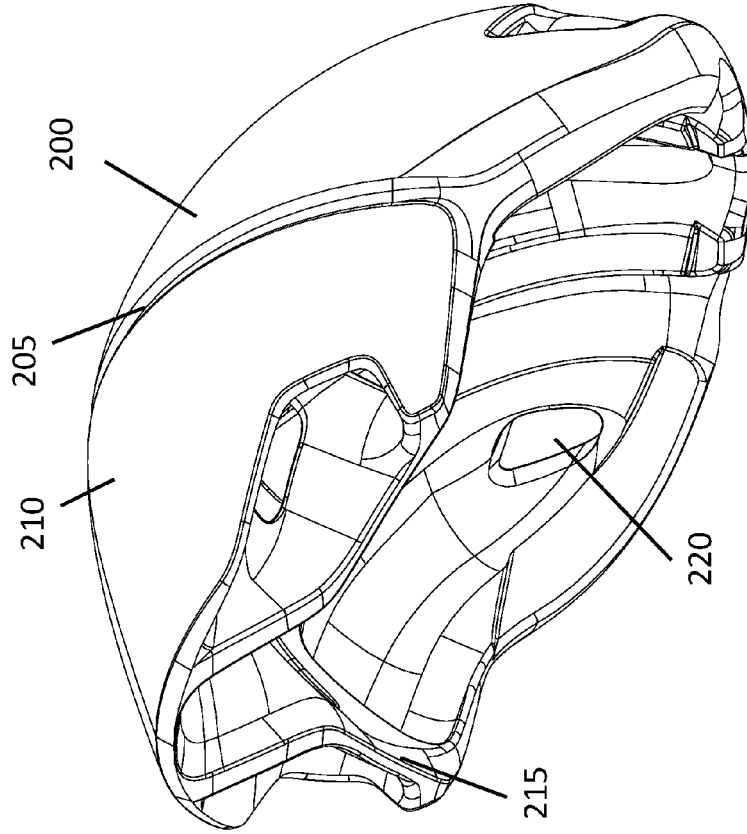


Fig. 2F

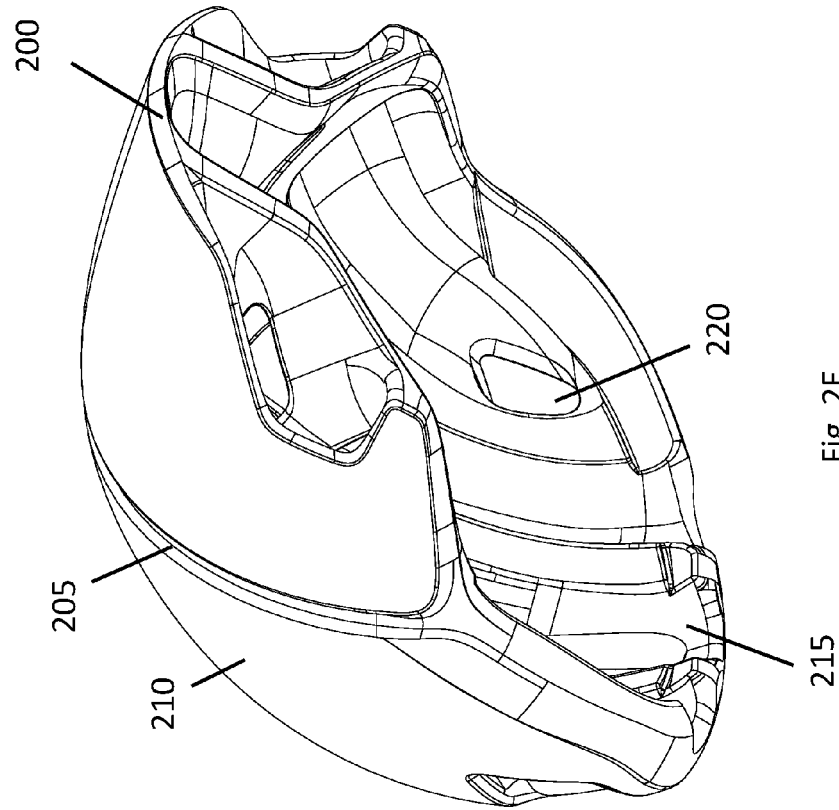


Fig. 2E

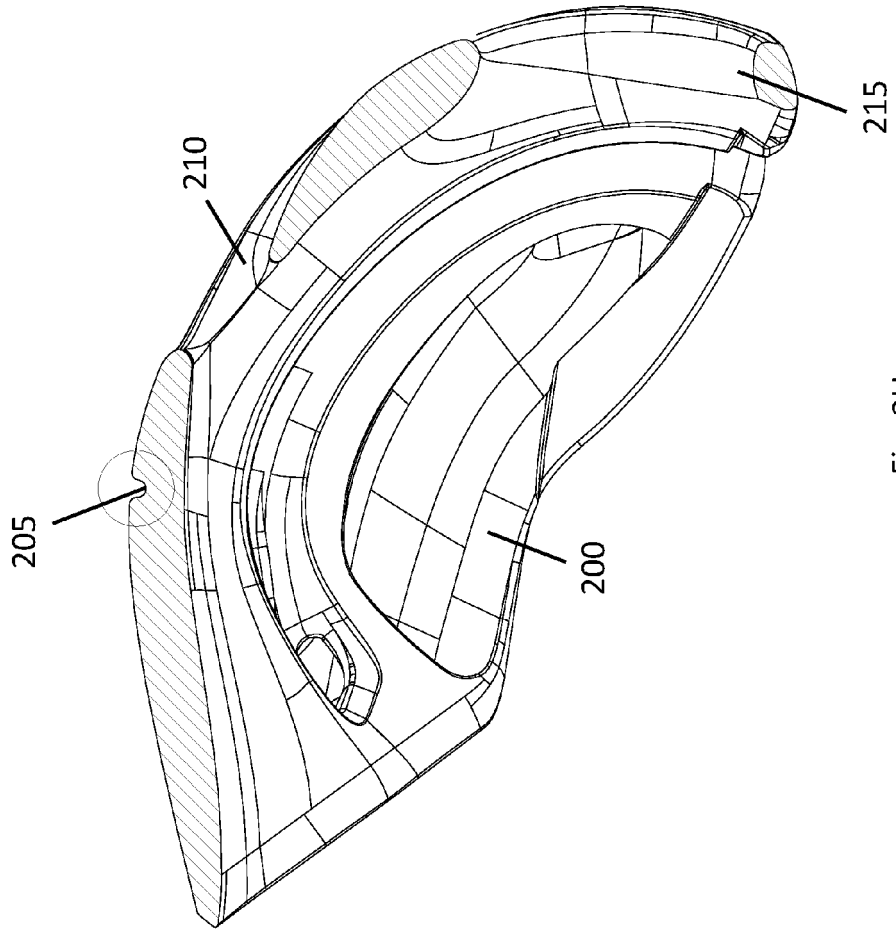


Fig. 2H

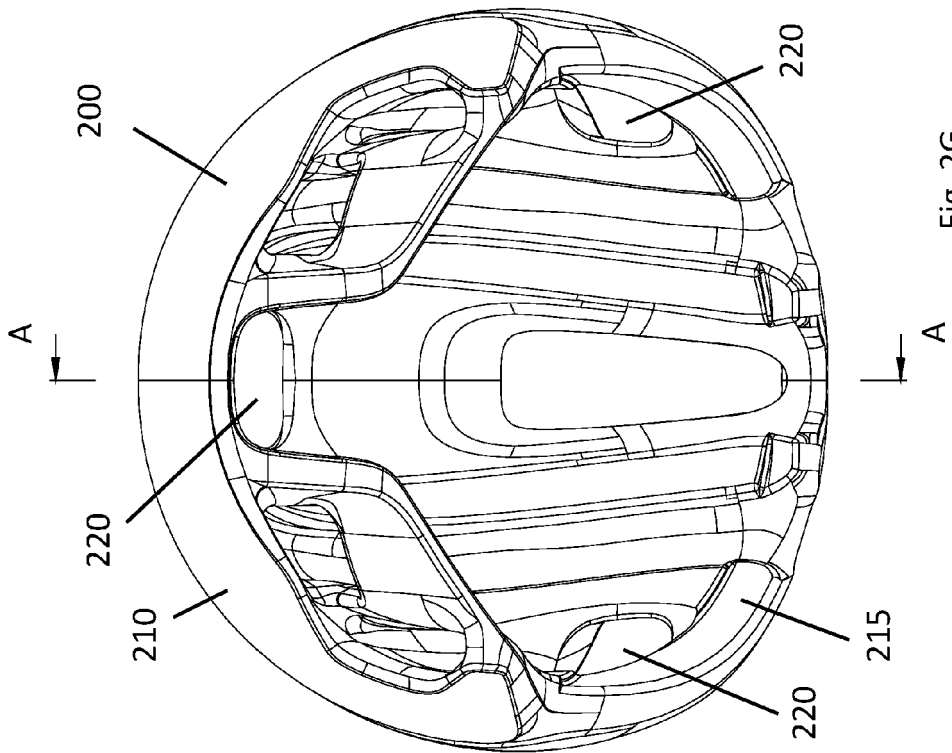


Fig. 2G

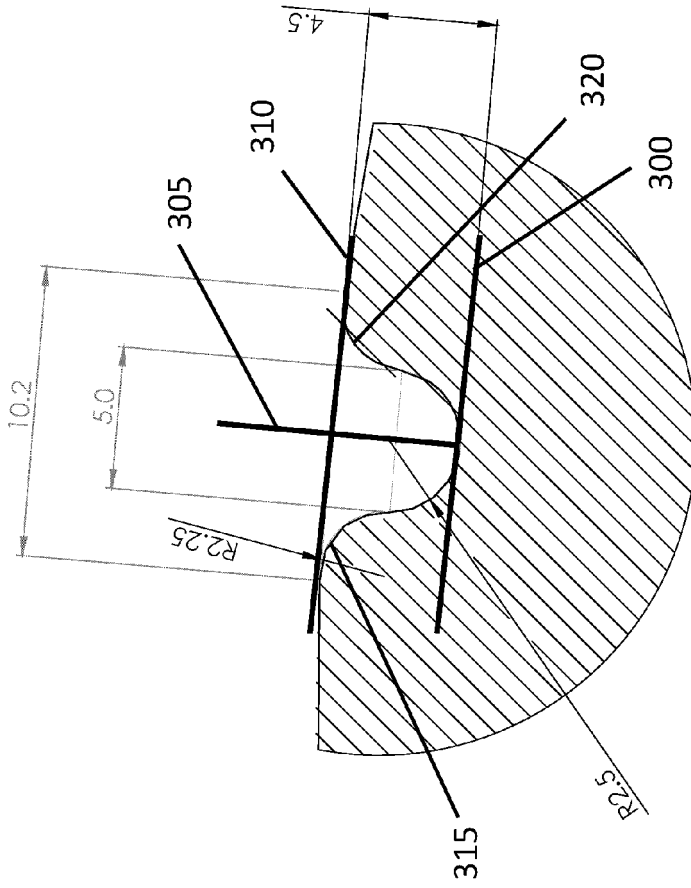


Fig. 3A

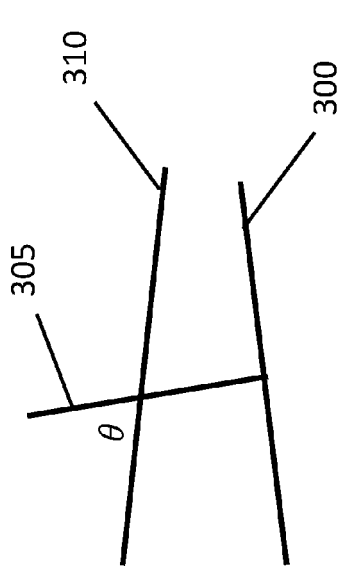


Fig. 3B

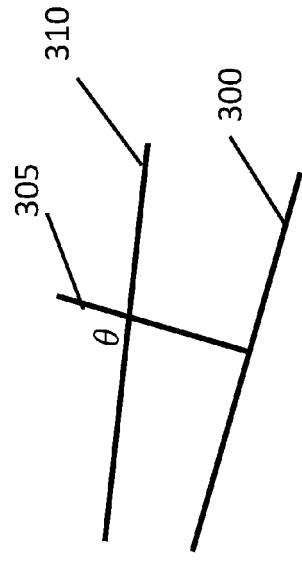


Fig. 3C

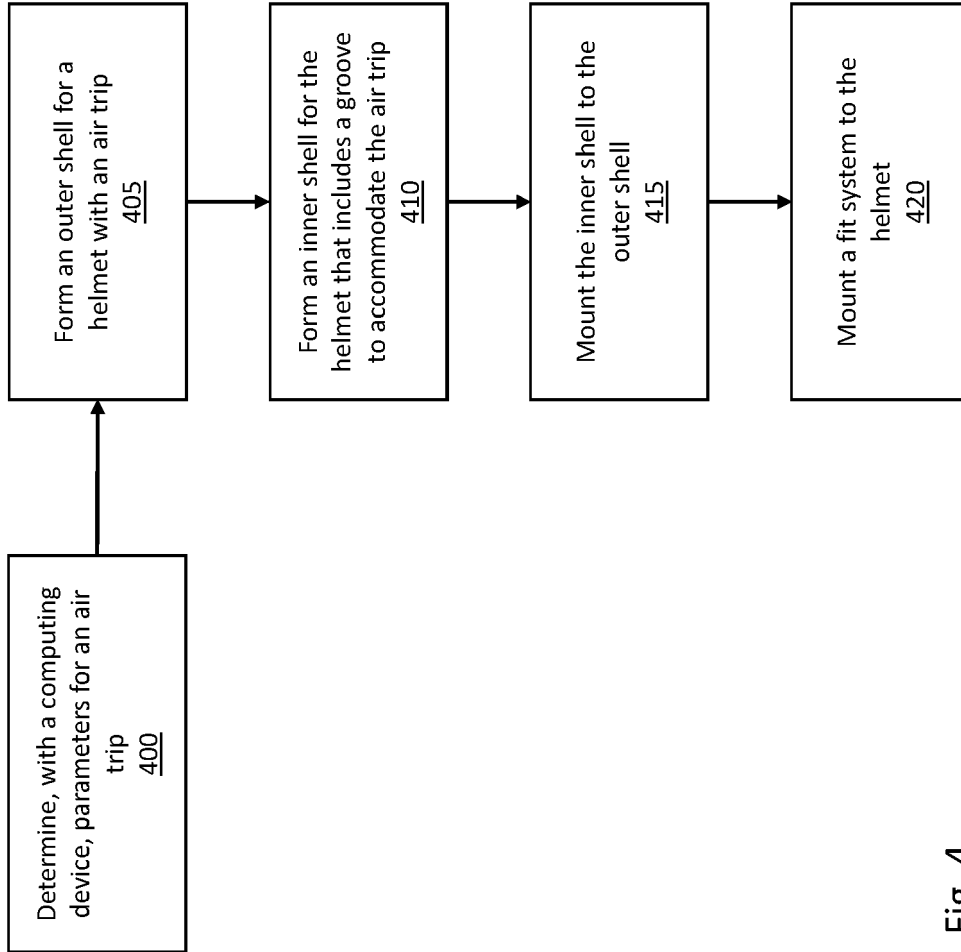


Fig. 4



EUROPEAN SEARCH REPORT

Application Number
EP 23 17 0369

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A	DE 92 09 357 U1 (FES E.V.) 10 September 1992 (1992-09-10) * page 1; figure 1 *	1-15	
A	US 5 271 102 A (FEULING JAMES J [US]) 21 December 1993 (1993-12-21) * column 3, lines 31-54; figure 3 *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			A42B
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 22 August 2023	Examiner D'Souza, Jennifer
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

22-08-2023

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US 5271102	A	21-12-1993	NONE

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82