US 20060101559A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2006/0101559 A1
Moore, III et al. (43) Pub. Date: May 18, 2006

(54) **CUSTOM-FITTED HELMET AND METHOD OF MAKING THE SAME**

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(21) Appl. No.: **11/255,415**

(22) Filed: **Oct. 20, 2005**

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/933,580, filed on Sep. 3, 2004, which is a continuation-in-part of application No. 10/727,725, filed on Dec. 4, 2003.

(60) Provisional application No. 60/432,193, filed on Dec. 6, 2002. Provisional application No. 60/620,906, filed on Oct. 21, 2004.

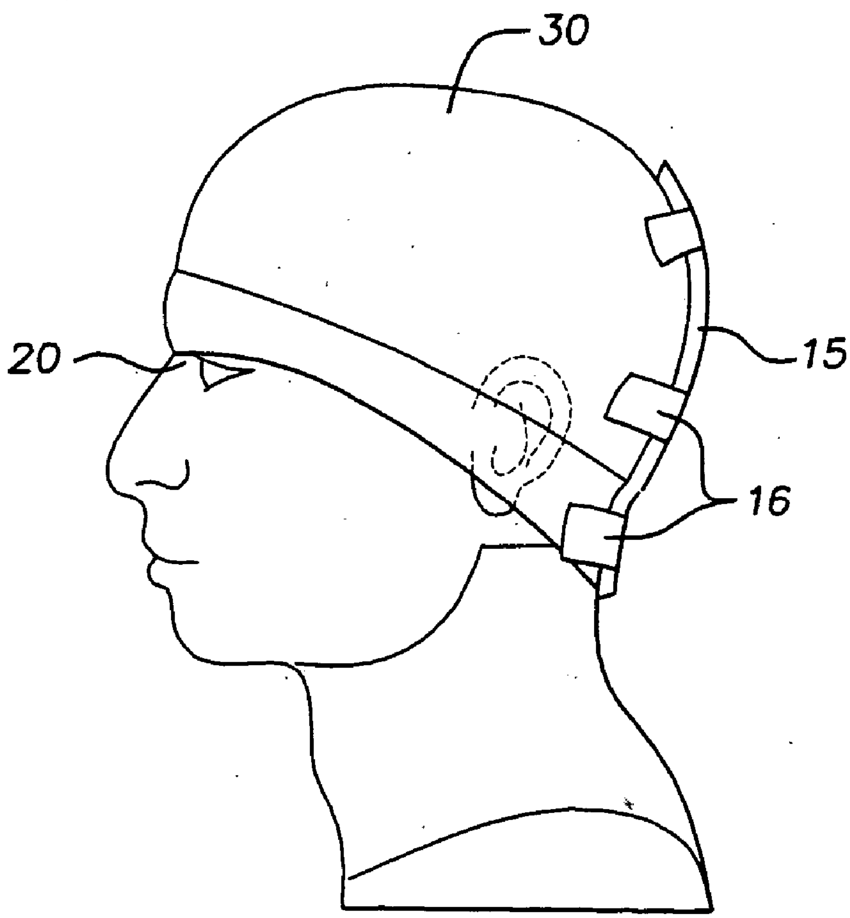
Publication Classification

(51) **Int. Cl.**
A42B 1/06 (2006.01)

(52) **U.S. Cl.** **2/410**; 2/411

(57) **ABSTRACT**

A helmet liner that is custom-fitted to a wearer's head, and methods of making the liner, are provided. To make the liner, scanning equipment directly scans the person's head to generate computer-readable data containing a surface map of the head. This data then is used by suitable machining equipment to machine a custom-fitted liner from a universal liner blank, whose resulting convex surface will substantially conform to the shape and contour of the person's head. The scanning equipment desirably is or includes one or a plurality of lasers. A mobile platform including both the scanning and the machining equipment also is provided.



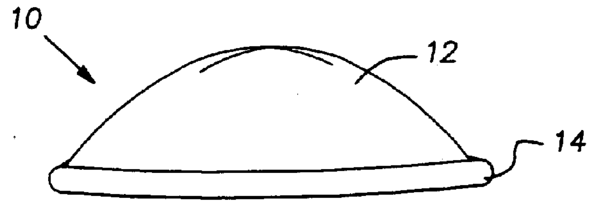


FIG. 1

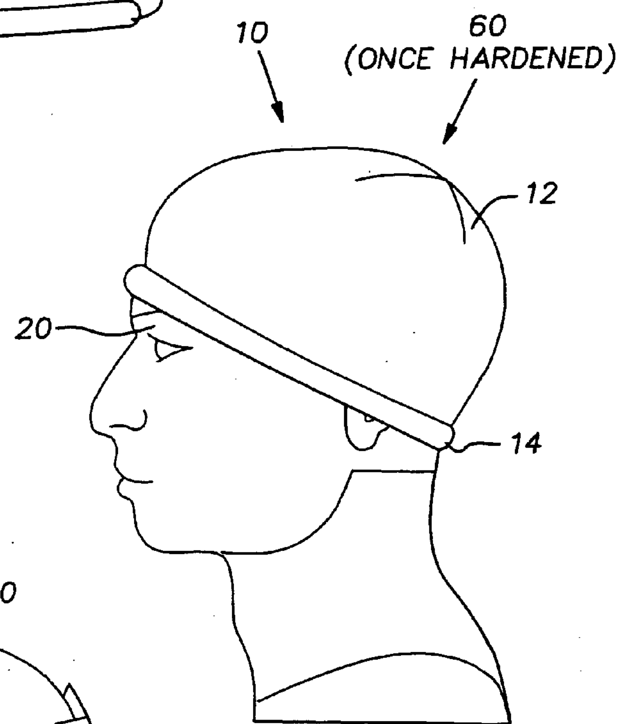


FIG. 2

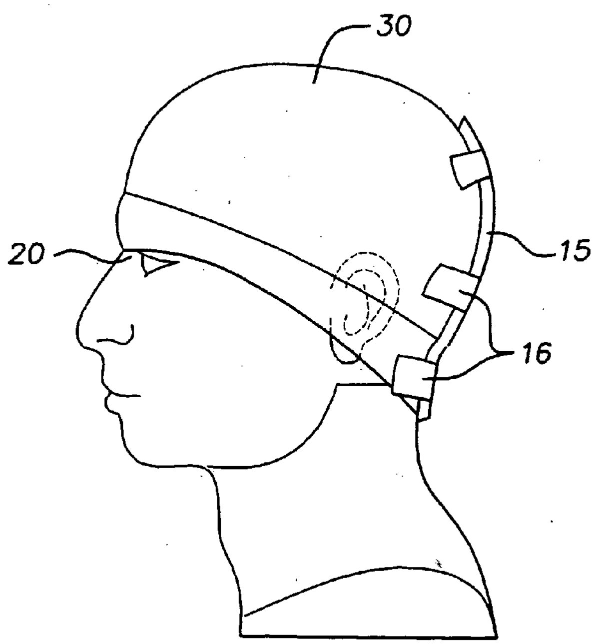


FIG. 3

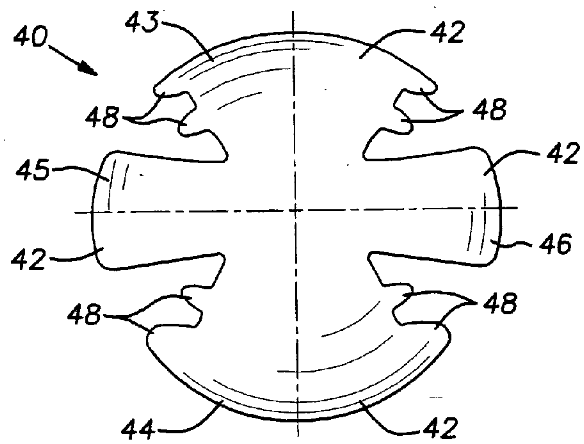


FIG. 4

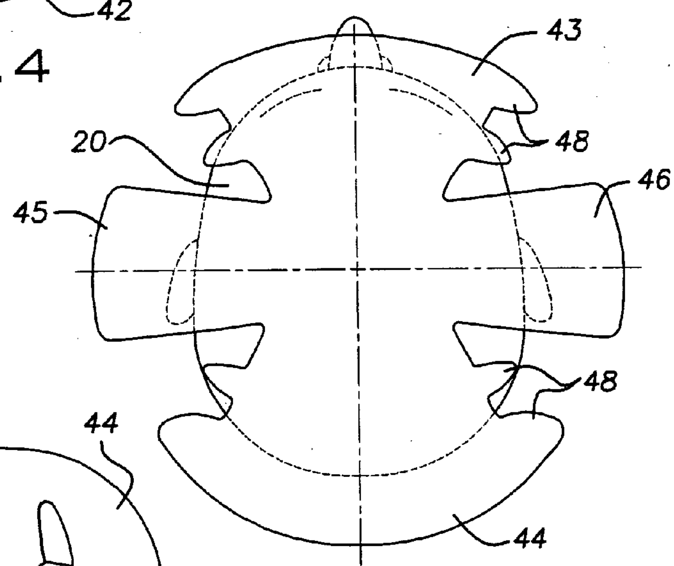


FIG. 5

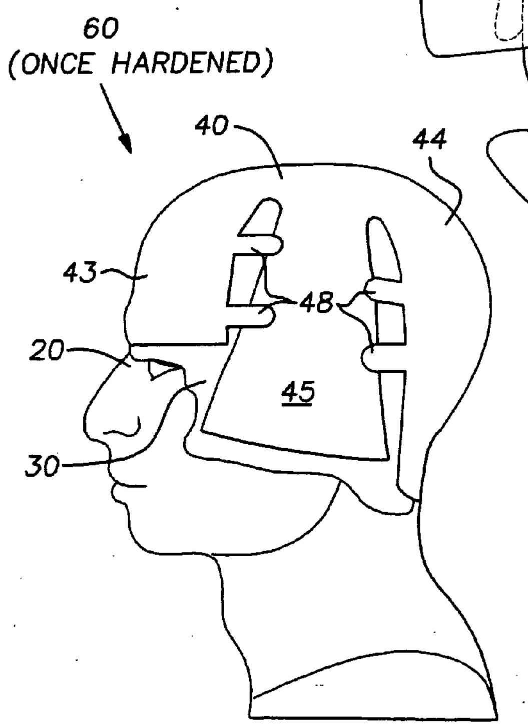


FIG. 6

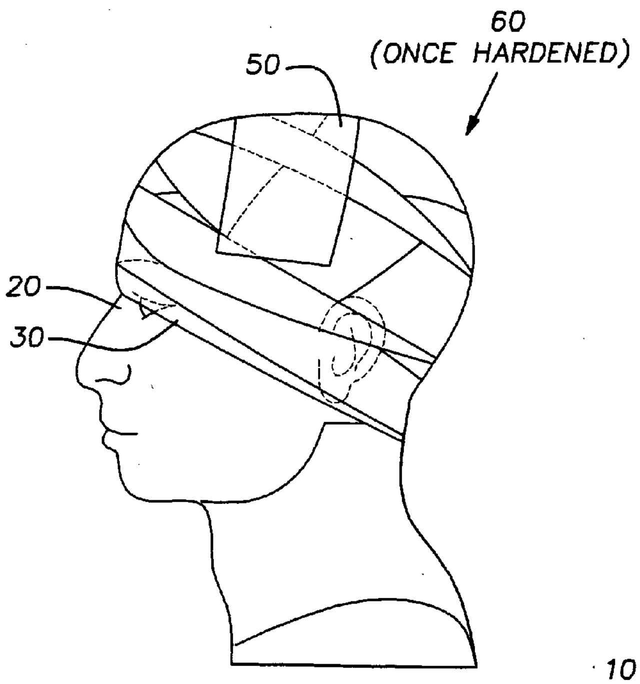


FIG. 7

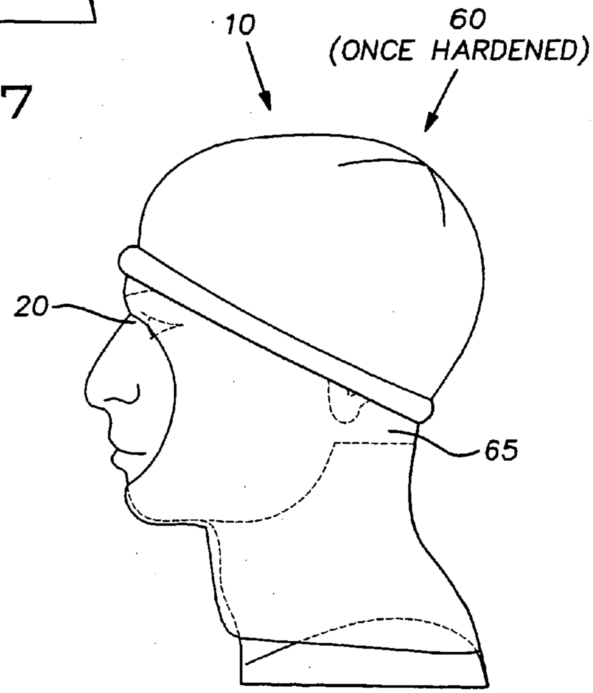


FIG. 8

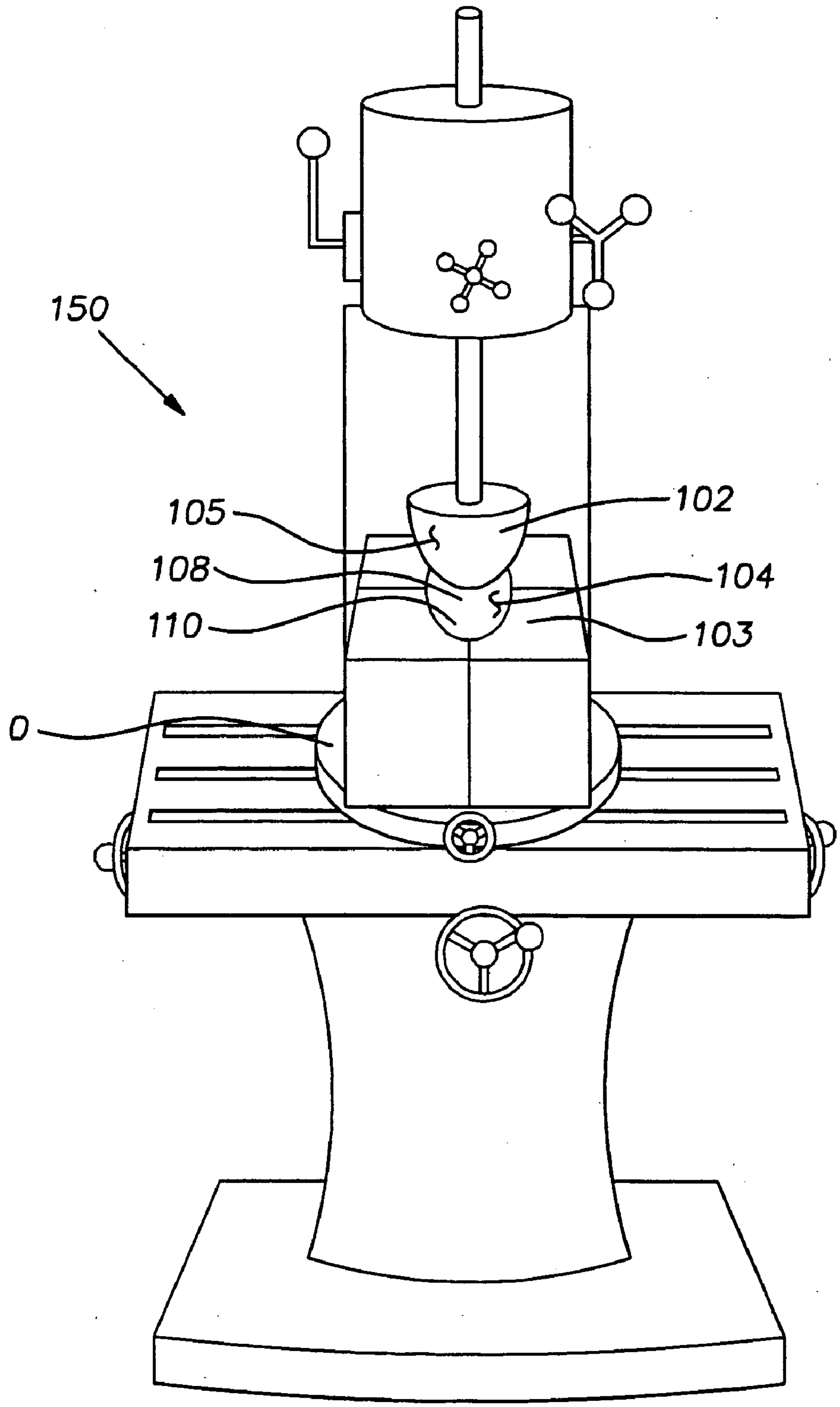


FIG. 9

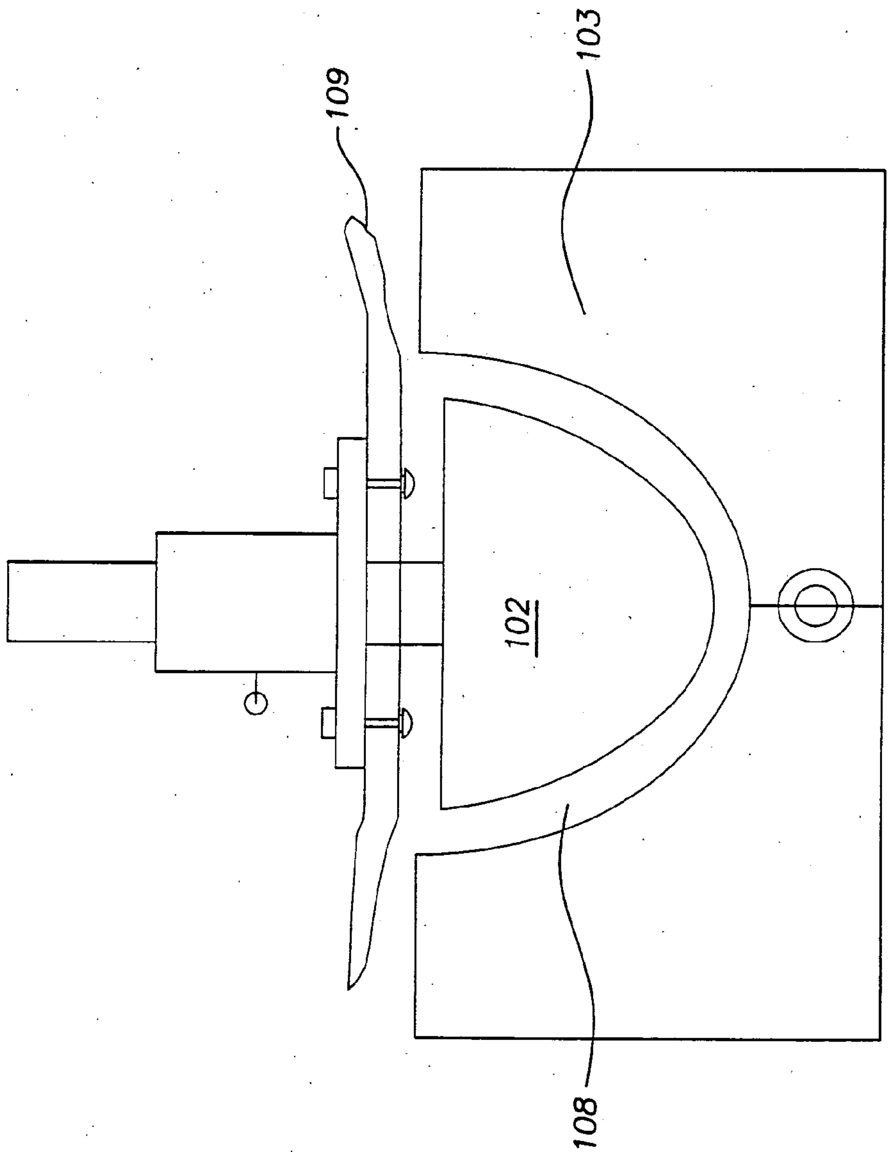


FIG. 10

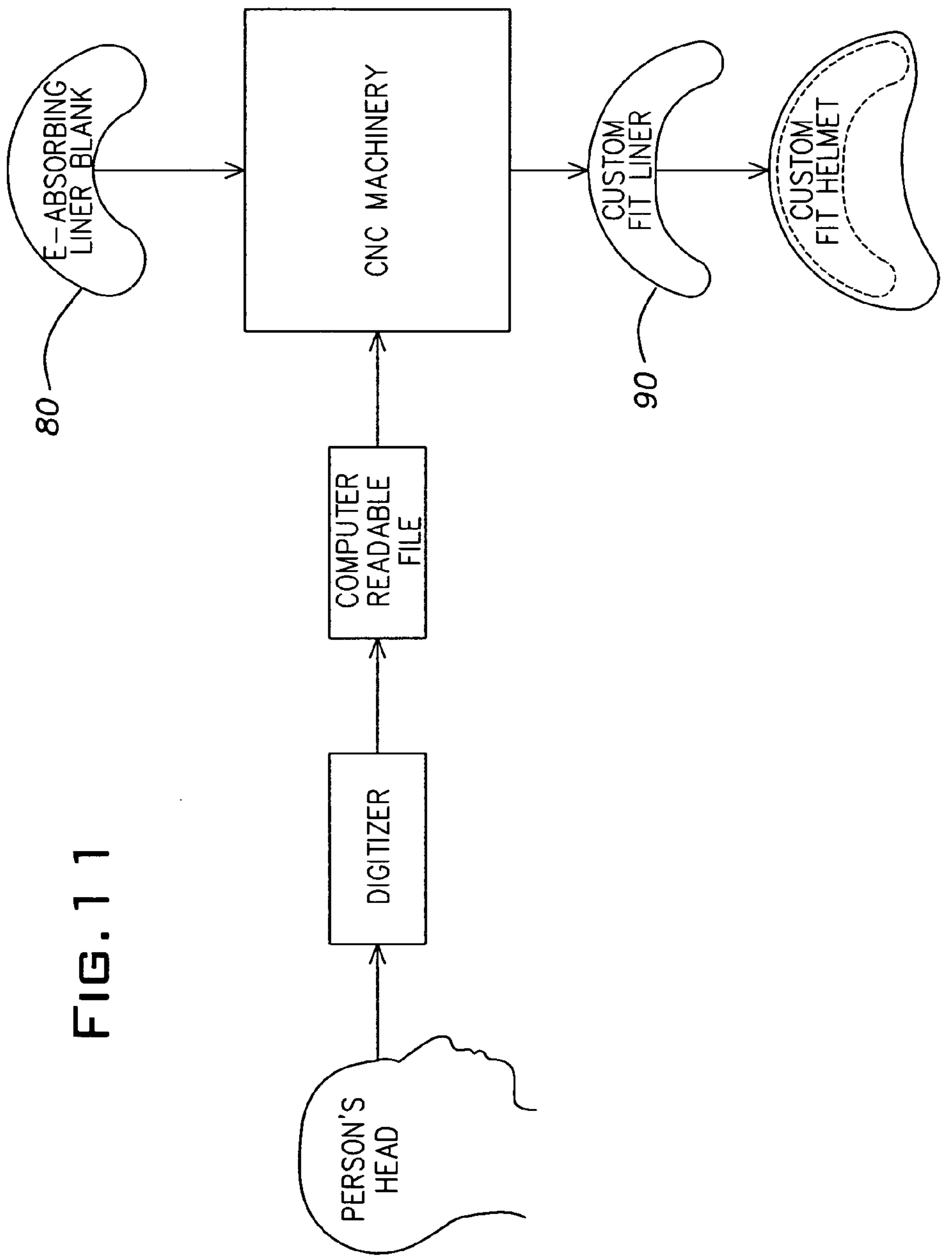

E–ABSORBING LINER BLANK
80
CNC MACHINERY
CUSTOM FIT LINER
90
CUSTOM FIT HELMET
COMPUTER READABLE FILE
DIGITIZER
PERSON'S HEAD

FIG. 11

CUSTOM-FITTED HELMET AND METHOD OF MAKING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No. 60/620,906 filed Oct. 21, 2004, and also is a continuation-in-part of U.S. patent application Ser. No. 10/933,580 filed Sep. 3, 2004, which is a continuation-in-part of U.S. patent application Ser. No. 10/727,725 filed Dec. 4, 2003, which claims the benefit of U.S. Provisional Patent Application Ser. No. 60/432,193 filed on Dec. 6, 2002, all of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The invention relates to a method of making a custom-fitted helmet. More particularly, it relates to a method for making a custom-fitted helmet having an impact energy-absorbing liner having an inner surface that substantially conforms to the shape of the wearer's head.

[0004] 2. Description of Related Art

[0005] Helmets having an impact energy-absorbing liner are known for all sorts of applications, including cycling, football and other contact sports, medical intervention for persons prone to seizures, industrial protection such as for manufacturing and construction workers, military and other aircraft pilot protection, etc. In all of these applications, the impact energy-absorbing liner is designed to absorb and/or dissipate energy from an impact at the outer shell of the helmet before it is transmitted to the wearer's head. In this manner the wearer's head is at least partially shielded or protected from what otherwise would be the full impact force resulting from the impact.

[0006] Conventionally, helmets are supplied in a plurality of standard sizes, e.g., large, medium, small. Sometimes the standard sizes are based on average head circumference, e.g. 14, 14.5, 15, 15.5, 16, inches, etc. A problem with this method of sizing helmets is that the helmets are sized based on universal standards that are not specific to any individual who will actually wear and depend on the helmet for head protection. While a standard sized helmet may provide adequate protection in some instances, it is not fitted to the unique shape and contour of the particular wearer's head, and therefore is prone to fit too tightly in certain aspects or along certain locations of the head while fitting too loosely in others. A too loosely fitting helmet can be harmful because the initial impact against the outer helmet shell can be transferred to the head during a second impact between the head and the loosely fitting interior surface of the helmet. Whereas a too tightly fitting helmet is uncomfortable to the wearer and can actually cause injury.

[0007] Currently, "off-the-shelf" helmets are fitted so that they fit snugly in the tightest dimension of the head—this could be from front to back, or it could be from side to side. The other dimension (front to back or side to side) is then looser—often with a gap of ½ inch or more on each side. This gap is often filled with non-energy-absorbing foam. As an example, a high performance ski helmet typically has approximately 1 inch of energy-absorbing polymer. The ½ inch of unused space on each side of the helmet comes at a high price from an energy-absorbing standpoint, because even at moderate impact speeds (e.g. 6 m/s) that extra ½ inch of energy-absorbing foam would result in about a 30% improvement in g-force attenuation prior to reaching the wearer's head. At higher speed impacts the improvement would generally be higher due to the fact that thinner foam will 'bottom out' sooner as impact speed increases.

[0008] For these reasons, it is important and desirable that the inner surface of the helmet fit as uniformly and snugly as possible about the shape and contour of the individual wearer's head, without being so tight as to result in discomfort or injury. Conventionally, helmets have been fit to a wearer's head either by shimming the inside of the helmet using energy-absorbing or comfort fitting foam pieces of varying thickness until the proper fit is achieved, or by installing a series of foam pieces of different thickness to provide a proper fit. There are two disadvantages of these methods: 1. It is difficult when fitting a helmet to know when you have achieved the proper fit. It is a trial and error process that requires more training than is typically available in retail stores. An improperly fitted helmet can lead to serious consequences. 2. Energy-absorbing foam is more effective if it is in one piece. The reason for this is that a significant amount of energy is absorbed in the foam by pumping air through foam—the larger the piece of foam, the longer the path the air must take, and the better the energy-absorption. If the foam is in several layers or discrete pieces, it is easier for the air to escape and the energy-absorption properties are reduced.

[0009] Some manufacturers attempt to fit their helmets to wearer's heads using "fitting pads" of highly compressible foam that has no appreciable energy-absorbing capability. These fitting pads help keep the helmet tight on the head rather than provide an additional layer of energy-absorptive material. As will be apparent from the above discussion, the use of any more than a minimum of fitting-foam is a waste of critical space in a helmet that could be used to absorb additional energy.

[0010] There is a need in the art for a method of making a custom-fitted helmet that is economical and comfortable to the wearer, where the energy-absorbing liner is snugly and uniformly fitted to the shape and contour of the head.

SUMMARY OF THE INVENTION

[0011] A method of making an energy-absorbing liner that is custom-fitted to a wearer's head is provided. The method includes the following steps: a) directly scanning a person's head and generating computer-readable data including a surface map of the person's head; b) providing a pre-made energy-absorbing liner blank having at least one surface; and c) machining the at least one surface of the energy-absorbing liner blank, based on the computer-readable data, to provide a convex surface therein whose shape and contour substantially conform to the shape and contour of the person's head.

[0012] An apparatus for producing a custom-fitted energy-absorbing liner is provided. The apparatus includes means for directly scanning a person's head to generate computer-readable data comprising a surface map of said person's head, and means to machine an impact energy-absorbing liner blank to provide a convex surface therein whose shape and contour substantially conform to the shape and contour of said person's head. Both the means for scanning the head and the means for machining the liner blank are provided on a mobile platform.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **FIG. 1** is a side view of a beanie cap for preparing a headform that can be used to make an energy-absorbing liner for a helmet according to the invention having an inner surface substantially conforming to the shape and contour of a person's head.

[0014] **FIG. 2** is a side view of a person's head to which the beanie cap of **FIG. 1** has been applied and rolled down and/or stretched over, substantially conforming to the shape and contour of the person's head.

[0015] **FIG. 3** is a side view of the person's head from **FIG. 2** prior to application of the beanie cap, and showing a barrier applied over the person's head according to the invention, and also showing a piece of flexible tubing attached along the centerline of the rear of the person's head as a scissor guide.

[0016] **FIG. 4** is a top plan view of a heat-softenable plastic sheet that can applied over a person's head and used to make a headform according to the invention for subsequently making an energy-absorbing liner for a helmet having an inner surface substantially conforming to the shape and contour of the person's head.

[0017] **FIG. 5** is a top plan view of the heat-softenable plastic sheet of **FIG. 4**, shown positioned atop a person's head prior to folding the individual elements over the head to conform to the head's shape.

[0018] **FIG. 6** is a side view of the heat-softenable plastic sheet of **FIGS. 4-5**, shown positioned over and substantially conforming to the shape and contour of the person's head.

[0019] **FIG. 7** is a side view of a person's head over which a curable tape has been wrapped to provide a headform according to the invention for subsequently making an energy-absorbing liner for a helmet having an inner surface substantially conforming to the shape and contour of the person's head.

[0020] **FIG. 8** is a side view of a person's head having a hardened headform substantially conforming to the shape and contour of the person's head which was made using the beanie cap of **FIGS. 1-2**, where a tight fitting elastic hood has been applied over the head prior to application of the beanie cap to protect the person's eyes, hair and scalp.

[0021] **FIG. 9** is a schematic representation of an energy-absorbing liner forming operation where a "male" mold member is suspended above a universally adjustable "female" mold member to define a molding space therebetween for molding an energy-absorbing liner according to the invention.

[0022] **FIG. 10** schematic side view of the "male" and "female" mold members from **FIG. 9** shown in a molding position and defining the molding space for the energy-absorbing liner therebetween.

[0023] **FIG. 11** is a schematic process diagram for making a custom-fitted helmet using CNC machinery according to a preferred embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

[0024] As used herein, when a range such as 5 to 25 (or 5-25) is given, this means preferably at least 5 and, separately and independently, preferably not more than 25.

[0025] One method of the present invention includes first making a headform that conforms to the shape of the wearer's head. The headform is made by positioning or wrapping an appropriate shape-forming means over and against the wearer's head. When the shape-forming means is applied to the head, it is in a softened or flexible state such that it can bend or flex or stretch to conform to the unique contour of the individual head to which it is being applied. Once the shape-forming means has been applied and conformed snugly to individual's head, it is hardened or rigidized such that it is no longer soft or flexible, thereby yielding a hardened headform **60** that conforms or substantially conforms to the shape and contour of the wearer's head.

[0026] Once hardened, the headform is carefully removed from the wearer's head so as not to break or deform the hardened headform, except for a scissor cut which may be employed to aid removal of the headform, as described below. (It is noted the headform may undergo additional hardening or curing after it is removed from the wearer's head). The headform is then used, in a manner described below, to mold (or to prepare a mold for) an impact energy-absorbing liner for a helmet that has an inner surface conforming or substantially conforming to the unique shape and contour of the head from which the hardened headform was made. Alternatively, in a further preferred embodiment described more fully below, the hardened headform can be scanned by suitable scanning equipment to generate a computer-readable data file of a surface map of the headform (i.e. digitizing the headform). This data file is then used to direct CNC machinery, or other computer controlled milling device or tool, to machine a pre-made energy-absorbing liner "blank" so as to provide an inner surface thereof having a complementary contour to the wearer's head. In a further embodiment also described below, the scanning equipment can scan the wearer's head directly to generate the computer-readable data in the manufacture of a custom-fitted liner.

[0027] As used herein, the shape-forming means can be a stretchable beanie cap that is coated or impregnated with a curable polymeric material, a heat-softenable plastic sheet, or a strip or plurality of strips of curable tape that are wrapped about the wearer's head to provide a headwrap. Each of these is now described in detail.

[0028] Referring to **FIG. 1**, a stretchable beanie cap **10** according to a preferred embodiment of the invention is shown. The beanie cap **10** is made from an elastic material such that it is stretchable and recoverable. By recoverable, it is meant that if stretched from its relaxed orientation in its uncured state, the beanie cap **10** will tend to return to its initial shape at rest once the external stretching force has been removed. This is important to ensure that the beanie cap **10** conforms to the unique curvature and contour of a wearer's head after it has been stretched thereover; i.e. to ensure the beanie cap **10** is snugly and elastically retained against the shape of the head over its entire surface of contact.

[0029] The beanie cap **10** can be made from an elastic polymeric fabric, such as the conventional Spandex™ or Lycra™ fabrics known in the art, alternatively glass fibers and fabrics can be used. In a preferred embodiment, the fabric used in beanie cap **10** is a knitted polyester fabric. Typically it is either knitted or assembled with fabric cut on the bias so the fabric has an elastic property and can stretch so as to conform tightly to the head and accommodate variations in head shapes. The beanie cap **10** is coated, preferably impregnated or saturated with a curable polymeric material, such as a curable polymer resin, that cures to a hardened state. In a preferred embodiment, the curable material is a moisture or water curable polymer that cures to a hardened state on exposure to moisture. U.S. Pat. No. 5,228,164, incorporated herein by reference, describes a knitted fabric material impregnated with a water curable polymer resin that is suitable for use in making the beanie cap **10** of the present invention. Alternatively, a suitable knitted polyester fabric material for making the beanie cap **10** is available by Carolina Narrow Fabric Company (Winston Salem, N.C.). The fabric is impregnated with a water-curing urethane polymer. The water curable polymer cures slowly when exposed to moisture in the air, or rapidly if water is applied directly to it. Additionally, other suitable curable polymeric materials can be used in the beanie cap **10**, and such materials can be selected by a person having ordinary skill in the art without undue experimentation. For example, other light or heat curing polymer resins can be used.

[0030] As supplied, the beanie cap **10** has a generally tubular structure that is open at one end and terminates at the other end in a closed, substantially dome shape portion **12** as evident from **FIG. 1**. Most preferably, the beanie cap **10** has a continuous knitted structure with no seams. In a preferred embodiment illustrated in **FIG. 1**, the beanie cap **10** has a substantial portion of its tubular length rolled up into a roll **14** that is disposed circumferentially about the dome shape portion **12** of the beanie cap **10**. In this embodiment, the beanie cap **10** is easily and uniformly snugly applied over and against a wearer's head by first aligning and placing the dome shape portion **12** against the apex of the head, and then with the dome shape portion **12** held in place, unrolling the tubular portion of the beanie cap **10** from the roll **14** over the head **20** such that the beanie cap **10** extends downward from the dome shape portion **12** against the surface of the wearer's head **20**. This process is best illustrated in **FIG. 2**. It will be apparent from **FIG. 2** that it is not necessary that the beanie cap **10** be unrolled an equivalent length all the way around; i.e. it may be necessary to unroll a portion of the beanie cap **10** to a greater extent adjacent the rear and side portions of the head **20** than adjacent the forehead to ensure complete and effective head shape coverage. This is expected and intended in the present invention, and such uneven stretching/unrolling of the beanie cap **10** is accommodated by the elastic property of the beanie cap material as described above. The beanie cap **10** must be unrolled or pulled down over the head sufficiently in every direction to match the head coverage of the energy-absorbing liner that will be made using the headform made by hardening the beanie cap **10** (described below). The location of the eyebrows, the ears, the occipital ridge, the centerline of the head and the fore and aft horizon of the head preferably are marked on the beanie cap **10**.

[0031] Alternatively, the beanie cap **10** is provided having no such roll **14**, such that its tubular length is not rolled up. In this embodiment, the beanie cap **10** is stretched over the wearer's head, and after it is tightly fitted, a terminal portion of the tubular length of the cap may be folded up or back on itself or cut away so as not to cover the wearer's eyes and to facilitate removal of the hardened headform once it is complete.

[0032] Once the beanie cap **10** is stretched snugly over the contour of the wearer's head **20**, the coated or impregnated polymeric material of the beanie cap **10** is cured or allowed to cure to yield a hardened headform **60** from the beanie cap, in the shape and contour of the wearer's head **20**. When the preferred water curable resin is used, the beanie cap **10** preferably is submerged or dipped once into warm water to initiate the curing process prior to applying the beanie cap to the wearer's head. Additionally, hot water can be sprayed onto the beanie cap **10** once it is applied to the head to further accelerate curing. Water vapor or ambient moisture also can be used but will result in a slower-rate cure, which may be desirable in some applications, e.g. if minor adjustments are to be made to the beanie cap against the wearer's head as the cap is cured.

[0033] After the headform **60** has hardened, it is carefully removed from the head and used in subsequent molding or scanning operations described below. To remove the hardened headform it is sometimes necessary to cut the headform (e.g. with scissors) adjacent the back of the head to facilitate removal. If desired, a piece of flexible tubing **15** such as polyethylene tubing can be placed along the centerline of the rear of the person's head as a scissor guide prior to fitting the beanie cap **10** over the head. (**FIG. 3**) The tubing **15** can be held in place by any suitable means, e.g. by strips of tape **16** as shown in the figure. The flexible tubing **15** aids cutting the hardened headform for removal once the curable resin has cured and hardened without risking cutting the hair or the scalp. Therefore, the tubing **15** extends at least partially below the terminus of the beanie cap **10** when unrolled against the rear of the head **20**. If used, preferably the tubing **15** has an outer diameter of about or less than ½ inch, preferably ¼ inch, preferably ⅛ inch, so as not to substantially interfere with the beanie cap **10** being snugly fitted to the head **20**. Because the tubing **15** is flexible, it can be compressed by the beanie cap **10** thereby further reducing the tubing's impact on the snugness of the beanie cap fit. Alternatively, instead of plastic tubing **15**, a flat piece of flexible plastic or plastic strip can be used as a scissor guide. When the plastic strip is used, it is affixed (i.e. taped) against the wearer's head, preferably beginning above the occipital ridge, such that it extends downward to just below the lower terminus of the beanie cap **10** as applied to the head. When the plastic strip is used, the rear side of a scissor blade is guided along its length when making the scissor cut such that the strip protects the wearer's head (and barrier **30** if provided) from being cut by the scissors. Once the headform is removed, the two edges of the scissor cut are rejoined and fastened by staples or super glue, or other suitable fastener. As a further alternative, a zipper can be provided in the beanie cap such that once the cap is hardened to produce the hardened headform, the zipper is simply unzipped to permit removal of the headform from the head.

[0034] Because the beanie cap **10** is coated or saturated with a polymeric resin, it is desirable to place a barrier over the wearer's head **20** prior to fitting the beanie cap **10** thereover. Such a barrier **30** is shown schematically in **FIG. 3**, and can be in the form of a plastic film or sheet that has a thickness of less than about 2 mm, preferably less than about 1 mm or 0.5 mm. Latex films generally are water impermeable, and so these are desired for the barrier **30** when a water cured resin is used in the beanie cap **10** to prevent the wearer's head and hair from getting wet with resin and/or water. In addition, latex also is substantially impermeable to the polymeric resins used in the invention and are also desirable for this reason. However, the barrier also can be made from other suitable materials, such as plastic films or even fabrics, so long as the material used will prevent or substantially prevent penetration of the curable resin and contact of the resin with the wearer's head. It is not necessary that the fabric be impermeable to the resin material; so long as it will not become saturated with the resin in the time it takes to complete the headform making process, the barrier **30** will provide adequate protection for the wearer's head. Preferably, the barrier **30** will cover the person's eyes, nose, and a substantial portion of the neck in order to shield the person from contact with the urethane or other resin.

[0035] Preferably, the barrier **30** has an elastic or stretchy property so it can be snugly and tightly fit against the wearer's head in order to minimize or prevent spacing defects between the finished headform **60** and the wearer's head. Once the barrier **30** is in place, the beanie cap **10** is placed over the head **20** (and over barrier **30**) and the process is completed as described above. To protect the person being fitted from water, a smock or protective covering should be worn. Gloves should be used when fitting the beanie since the resin will stick to hands and can cause irritation.

[0036] **FIGS. 4-6** illustrate a heat-softenable plastic sheet **40** according to the invention as well as a method of application to a wearer's head **20**. Preferably, the plastic sheet **40** is a heat-softening thermo-forming plastic sheet such as Polyform™ available from Sammons Preston Rolyan (formerly Smith & Nephew), Bolingbrook, Ill. Most preferably, the plastic sheet **40** is 1/16 inch or 1/8 inch thick, however other suitable thicknesses may be used. As shown most clearly in **FIG. 4**, the plastic sheet **40** is cut into the shape of a crude flower with between 3 and 10 "petals" or elements **42**. The crude flower shape is designed so that the plastic sheet **40** can be fitted adjacent its geometric center against the apex of the wearer's head **20** (see **FIG. 5**) with individual elements **42** folded or draped down over and against the wearer's head (**FIG. 6**). In the illustrated embodiment, four elements **42** are shown extending generally outward from the center-most portion of the sheet **40**: a frontal element **43**, rear element **44**, and left and right lateral elements **45** and **46** respectively. The frontal and rear elements **43** and **44** each have a plurality of laterally extending tabs **48** which are used to aid fixing the sheet **40** in the shape and contour of the head **20** as will be further described. Alternatively, other appropriate shapes for the plastic sheet **40** can be used.

[0037] Initially, the heat-softenable plastic sheet **40** is heated above its softening temperature, typically to 65-70° C. Once softened, the heated plastic sheet **40** is draped over the head as described above and shown in **FIGS. 5-6**. To protect the forehead and ears from the heat and to keep the plastic from sticking to the hair, a thin bathing cap or a plastic film (barrier **30**) should be placed over the head before the heat-softened sheet **40** is applied. The plastic sheet **40** is pressed against the head in its softened state, e.g. by hand, and is held against the head until the plastic cools below its softening temperature and re-hardens. Once the plastic sheet **40** has been fitted and the individual elements **42** draped over and against the wearer's head, the laterally extending tabs **48** from the frontal and rear elements **43** and **44** are pressed against adjacent the lateral elements **45** and **46** to aid and define the shape of the plastic sheet **40** conforming to the wearer's head as the plastic cools and hardens to yield the hardened headform **60** conforming to the shape and contour of the wearer's head. If desired, a piece of flexible tubing can be used similarly as for the stretchable beanie cap described above as a scissor guide to aid removal of the hardened headform.

[0038] **FIG. 7** illustrates a preferred method of using a curable tape **50** to provide the hardened headform. Using curable tape to define the head shape is more time consuming and requires a skilled technician to apply the strip(s) of curable tape **50** properly. In this embodiment, the curable tape **50** preferably is provided in the form of a strip or strips of compliant material, such as fabric or other textile material or synthetic material, that is/are coated or impregnated with a curable polymeric material. Similar curable materials and/or resins can be employed as in the beanie cap embodiment. The compliant material preferably is made from glass fabric (such as fiberglass) for optimal stiffness, and is coated or impregnated with the curing resin. The curable tape **50** also can be made of a knitted thick, but porous, fabric or a bias cut fabric, including synthetic fabrics. If fabrics are used they must be thick enough to provide "section" but porous enough to allow permeation of the water necessary for curing when a water curable resin is used. A tape having a width of about 3-4 inches is preferred, noting it takes approximately 700 square inches to complete a head. A suitable resin-impregnated compliant fabric tape is 3M Scotchcast™ Plus Casting Tape (3M Health Care, St. Paul, Minn.), which is a knitted fiberglass fabric impregnated with a water-curable polyurethane resin. Alternatively, the curable tape **50** can be made from a strip or strips of curable polymeric material, such as strips of yet uncured polyurethane which can be hardened e.g. by contacting with water.

[0039] The tape **50** is wrapped around the head **20** as shown in **FIG. 7**, being careful to get the tape low enough so that the full head-contacting surface for the energy-absorbing liner for the helmet is defined. Just as in the above-described embodiments, a barrier **30** can be and preferably is employed to prevent or minimize contact of the resin or curing water with the wearer's hair or scalp. In this embodiment, the barrier **30** can be used in addition as a guide to indicate how far down on the head the tape **50** should be applied. As with the beanie cap, gloves should be used when applying the tape **50** and smock or a protective covering should be worn to protect the person being fitted. In the preferred embodiment, when the tape **50** is coated with a water curable resin, the tape is initially squeezed or wrung in warm water to begin the curing process, and is then wrapped quickly around the perimeter of the head, cut, and several layers are placed over the top of the head, so that the head is fully covered. A final wrap is made around the head just above the initial wrap to ensure that there are no gaps. The tape is gently wiped downward and pressed against the head until the tape hardens. When using the preferred water curing resin, the tape cures in less than 10 minutes when water is applied, yielding the hardened headform **60**.

[**0040**] Because the resin will cure (and consequently the tape will rigidize) quickly after being immersed in water, a skilled technician will be required to apply the tape properly before it has rigidized. In this embodiment, a certain level of practice is anticipated on the part of the technician to develop a sufficiently rapid wrapping technique.

[**0041**] Irrespective of which of the above shape-forming means is used to provide the hardened headform, care must be taken to cover the proper amount of the head so that the subsequently made energy-absorbing liner (molded from the headform, whose mold is made using the headform, or made using CNC machinery as described below) complies with the proper coverage standards and suitably covers the appropriate portions of the head. For example, for motorcycle helmets, the highest coverage standard is Snell M2000 or DOT FMVSS 218, for football helmets it is ASTM F429-01 or NOCSAE Doc. 002-96m98, and for bicycle helmets it is ASTM F1447-99a or CPSC Prt. 1203.

[**0042**] Also irrespective of which of the above shape-forming means is used to provide the hardened headform, preferably a clearance is provided to position a thin layer of comfort foam spacer or spacer(s) to provide for wearer comfort and allow for air circulation, as well as to accommodate the aesthetic lining or upholstering material that will cover all or part of the inside surface of the helmet. This clearance can be provided by placing a tight fitting elastic hood **65** as seen in **FIG. 8** having a hood thickness over the head prior to applying the shape-forming means thereover. The hood thickness preferably is approximately ⅛ to ¼ inches. This will result in the subsequently formed impact energy-absorbing liner having a larger interior dimension, providing the clearance for the comfort foam spacers and the upholstery material. An alternative method is to create the clearance on the "male" member of the liner mold (described below) by covering it with wax or stretchable material (such as silicone or latex material), or another material with the proper thickness that will provide the necessary clearance. In a further alternative, when the energy-absorbing liner is made using CNC machinery based on a digitized file of the headform surface contour, the digital headform map is manipulated using appropriate software to provide the desired clearance (described more fully below). In this case, it is not required to use a hood (**FIG. 8**) when making the headform.

[**0043**] Once the hardened headform has been made using any of the shape-forming means described above, it can itself be used as the "male" member, together with a suitable "female" member, of a mold for molding the impact energy-absorbing liner for the helmet. Alternatively, the hardened headform can be used as a mold cavity (previously occupied by the wearer's head) into which plaster or some other molding compound is poured, which will itself harden and then will be used as the "male" member of the mold for making the energy-absorbing liner. Each of these methods is now described with respect to **FIG. 9**.

[**0044**] In the first method, where the headform is itself used as the "male" member **102** of the mold, the headform is positioned adjacent and spaced a distance from the concave inner surface **104** of a "female" mold member **103** such that the exterior surface **105** of the headform and the inner surface **104** of the "female" mold member define a molding space **108** therebetween for molding the energy-absorbing liner. The molding space **108** will have very close to the same dimensions as the finished impact energy-absorbing liner as will become evident. When using the hardened headform **60** as the "male" member **102** of the mold, the exterior surface of the headform is sanded to eliminate defects such as exterior bumps, ridges, and wrinkles. Any holes in the headform also should be tightly taped both inside and out so that the expanding foam will not cause them to depress. Typically, the headform is then filled with a hardening material and a pipe or other handle is suspended in the hardening material until it is hardened. The pipe/handle allows the headform to be held and articulated. A layer of stretchable plastic or rubber may be stretched over the headform to create clearance for inserting foam spacers for air circulation if the wearer's head was not previously provided with an elastic hood **65** to provide such clearance as described above.

[**0045**] In the second method, Plaster of Paris (preferred) or other suitable plaster or curable/hardening material is poured or provided in its uncured state into the cavity defined by the hardened headform, and is then cured to provide a male fixture in the shape of the wearer's head from which the headform was made. In order to prepare the headform to cast the male fixture from plaster or other suitable material, it is important first to seal the headform with an appropriate sealant to make it water tight. If desired, a pipe or other handle structure can be inserted into the yet-uncured Plaster of Paris material and suspended in place until the plaster dries to facilitate handling and fixturing. When the plaster has cured, the hardened plaster fixture is removed from the headform and is lightly sanded to smooth and to remove ridges and irregularities. If the headform was hardened over the wearer's head without the elastic ⅛ inch to ¼ inch thick hood **65** in place (see above and **FIG. 8**), it may be necessary to provide a clearance for the foam spacers to be positioned between the energy-absorbing liner and the wearer's head in the finished helmet. A tight fitting urethane film, or a latex or silicone cover is believed to work effectively. In any case, the surface that is exposed to the foaming composition (described below) should be coated with a release coating so that the foam of the energy-absorbing liner will not stick to it once cured.

[**0046**] The "female" mold member **103** can be a conventional female mold member having a cavity **110** for molding foam or other resinous energy-absorbing materials, e.g. as shown in **FIG. 9**. Alternatively, the "female" mold member can be the outer helmet shell into which the liner ultimately is to be placed. In this embodiment, the liner is formed in situ, directly in the helmet shell and can bind to the inner surface of the shell as it cures.

[**0047**] Returning to **FIG. 9**, a schematic representation of an energy-absorbing liner forming operation is portrayed. While this schematic is shown having a conventional "female" mold member having cavity **110**, it will be understood that the principal of operation as displayed and further described will not be substantially different when the liner is formed directly into the outer helmet shell. In addition, "male" member **102** in **FIG. 9** schematically portrays the male member of the mold which conforms to the shape of the wearer's head for which the liner is being cast, and can be either the hardened headform or a plaster fixture made from the headform as above described. The apparatus shown in **FIG. 9** is similar to the structure of a Bridgeport milling machine, having a table **180** that is universally adjustable to provide precise alignment and adjustability between the "female" mold member **103** on the table, and the "male" mold member **102** suspended above.

[**0048**] To make the energy-absorbing liner, the "male" member **102** is positioned such that its exterior surface **105** is located adjacent and spaced apart a distance from the concave inner surface **104** of the "female" mold member **103**, such that the exterior surface **105** of the "male" member **102** and the inner surface **104** of the "female" member **103** define a molding space **108** therebetween having a substantially spheroid shape. To ensure uniformity of the spheroid molding space, the "male" member **102** and mold cavity **110** can be assembled to a press **150** as shown in **FIG. 9**, where the "male" member **102** is mounted to a retractable shaft that is adapted to centrally align the "male" member with the mold cavity **110**. Alternatively, other conventional or suitable alignment mechanisms may be employed.

[**0049**] Next, a curable compound is provided or injected into the spheroid molding space **108** to substantially fill that space, and is cured or allowed to cure to form the desired impact energy-absorbing liner. Most preferably, the curable compound is a liquid foam precursor composition that cures and expands to form an energy-absorbing foam.

[**0050**] The most preferred foam is a semi-rigid viscoelastic foam made from a two-part foaming composition, preferably, one part being isocyanate and the other part being a polyol or mixture of polyols. Most preferably, the foam is Zorbium™ foam available from Team Wendy, LLC in Cleveland, Ohio. Zorbium™ is an energy-absorbing foam that, unlike expanded polystyrene (EPS), exhibits substantially 100% crush recovery following an impact, yet it is still effective to absorb low to high energy impact forces (i.e. 2 to 4 as well as 4 to 7 m/sec, or anywhere in between) and dissipate much of the impact energy away from the head at the localized region of impact. Zorbium™ crushes more than EPS under low speed impacts, and yet has approximately the same crush as EPS under high speed impacts—it thus provides greater impact protection over a wider range of impact velocities. Less preferably, other known or conventional impact energy-absorbing foams or resins can be used, such as EPS or expanded polypropylene (EPP), vinyl nitrile, etc. Generally, when molding EPS or EPP steam is used to heat the precursor polystyrene/polypropylene beads. As the beads soften the soluble hydrocarbons expand to generate the foam. Therefore With EPS or EPP, the mold should be provided with a number of vent holes to permit venting of the steam.

[**0051**] The thickness and density of the impact energy-absorbing liner (preferably made from foam, preferably Zorbium™ foam) depend on a variety of factors, perhaps most importantly the anticipated or probable impact velocities, the composition of the outer helmet shell and the site and vector of probable impacts. Arriving at the precise foam composition and thickness for the impact energy-absorbing liner may involve matching the stiffness and strength of the outer shell with the stiffness of the foam taking into account the most critical impact velocities and vectors.

[**0052**] It is preferred to utilize the plaster fixture made from the hardened headform as the "male" mold member **102** because this fixture more accurately conforms to the shape and size of the wearer's head **20** because it is cast in the same cavity once occupied by the head. Using the headform **60** directly as the "male" member **102** of the liner mold is faster (omits a step) than making and using a plaster fixture, but is less precise and can result in greater irregularity in the finished foam liner. But even if this technique is used it may be necessary in some cases to stretch an elastic material over the headform as described to allow for more clearance for the foam spacers for air circulation in the helmet.

[**0053**] In a preferred configuration the "female" mold member **103** splits into four sections as shown in **FIG. 9** that slide out allowing precise measurement of the molding space between the "male" member **102** and the inner surface **105** of "female" member **103**. It will be understood that proper thickness and shape of this molding space **108** is important, because there is a minimum foam thickness for the energy-absorbing liner that is necessary for effective impact absorption. It is critical that the mold not be cocked to either side or front to back during molding. On the "male" member **102**, markings are made for the eyebrows, the position of the nose, for the position of the occipital ridge and for the fore and aft horizon of the wearer. Most preferably, these markings are made on the hardened headform **60** prior to removal from the wearer's head to precisely locate these features for the particular wearer. Alternatively, if a plaster fixture is made from the headform, these markings are transferred to the fixture as it is demolded from the headform. These markings will describe where the head will be positioned in the helmet, and help to align the "male" member to define the molding space.

[**0054**] It is important to pre-measure the volume to be foamed to fill the molding space **108**. Most preferably, this is achieved by first measuring the volume of the female cavity **110**, and then subtracting that portion of the "male" member **102** that is inserted into the cavity **110**, whose volume can be determined by water displacement. Once the precise volume of the molding space **108** for the energy-absorbing liner is known, the correct amount of the foaming compound can be mixed to achieve the proper density of the finished foam liner that will yield the proper energy-absorbing characteristics.

[**0055**] As shown in **FIG. 10**, once the "male" and "female" mold members **102** and **103** are in position defining the molding space **108** therebetween, a lid or collar **109** is placed at the opening of the female cavity **10** around the perimeter of the "male" member **102** to seal the molding space. The pre-measured foaming compound is then provided or injected into the molding space, e.g. through the collar **109**. As the compound foams and expands, it fills the molding space and rises to meet the collar, and the collar is held into place rigidly until the foaming pressure has subsided. Once foaming is complete, the collar is removed and the mold disassembled to retrieve the finished impact energy-absorbing foam liner having an inner surface substantially conforming to the shape and contour of the particular wearer's head. It is noted that according to the invention, the finished impact energy-absorbing foam liner is made as one piece, and not from multiple pieces that are subsequently joined via welding or other means. It is a one-piece liner whose inner surface is substantially uniformly and continuously snugly fitted to the wearer's head when the wearer is wearing the helmet, thereby eliminated localized pressure points between the liner surface and the wearer's head.

[0056] This liner is then fitted into an outer helmet shell and is upholstered with fabric and leather as may be desired to provide a custom-fitted helmet for the wearer. A thin layer of soft open cell comfort foam spacer or spacers (conforming to the clearance thickness described above) is typically placed between the upholstery and the impact absorbing foam to provide a space for air circulation, and holes are drilled in the foam to facilitate ventilation. Alternatively, if the helmet shell is used as the "female" mold member **103**, it will be understood the liner formed therein is not removed.

[0057] An alternative, further preferred method for making the custom-fitted helmet using the hardened headform also is provided. This method involves scanning the headform or a fixture made from the headform to generate a computer-readable data file containing a digitized map of the shape of the wearer's head, and using the digitized map to control CNC machinery to provide the corresponding surface contour on the inner surface of a pre-made energy-absorbing liner "blank." This method now will be described in detail.

[0058] In conjunction with the following description, reference is made to **FIG. 11** which schematically depicts a method for making a custom-fitted helmet using CNC machinery. In this method, the hardened headform **60** is produced as described above via one of the above-described methods. Alternatively, the headform **60** can be produced via any suitable method that is effective to produce a headform that conforms to the contour of a person's head. Preferably, the headform **60** is marked up with suitable contour lines and other suitable notation to indicate the relative positions on the headform corresponding to particular points on the wearer's head. For example, the headform may be marked with a line parallel to the ground to indicate up and down orientation, a point to indicate the location of the occipital ridge on the skull, lines indicating the positions of the eyebrows, and a point to indicate the center of the head (the nose).

[0059] Then the headform is delivered to a scanner or other suitable machine (such as a coordinate measuring machine) capable of scanning the headform using known or conventional methods, most preferably using lasers, to measure the surface dimensions and contour of the headform. The above-noted contour lines and other notation marked on the headform provide suitable reference points for the scanning machine to generate a corresponding electronic solid form model of the headform as known in the art (i.e. to digitize the scanned headform). Suitable scanners are available, e.g., from Cyberware, which produces a variety of laser-based scanners capable to generate three-dimensional solid form models in computer-readable form. The scanner is equipped with or coupled to a processor that is capable of generating electronic computer-readable data comprising a digitized surface map of the headform, corresponding to the wearer's head. This computer-readable data is then fed into or used by a computer controller that is coupled to suitable CNC machinery to control the operation of the machinery. The CNC machinery can be, e.g., a CNC router or any other known or conventional type of milling machine or tool that is amenable to CNC control so as to produce, via routing, milling or other machining operation of the machine or tool, an inner surface of a "blank" liner that conforms to the digitized surface map of the headform in the computer-readable data file. Such suitable CNC machinery, including CNC routers, are well known and conventional in the art and their operation will not be further described here.

[0060] To produce a custom fitted energy-absorbing liner using the suitable CNC machinery described above, an energy-absorbing liner blank is supplied and retained in a suitable fixture so that the CNC machinery can operate on the blank based on the information in the computer-readable data file. According to the invention, an energy-absorbing liner blank is made, e.g. via molding or other suitable means, whose outer convex surface conforms to the helmet shell in which the liner will be mounted, and whose inner concave surface is generally dome- or hemispherically-shaped. The inner concave surface is provided having a relatively small diameter compared to a typical human head. In this manner, the CNC machinery or router can produce a desired inner surface contour based on the digitized headform data map by milling, grinding away or otherwise machining liner material from the inner surface of the blank until the appropriate headform dimensions are achieved. Once the desired final inner concave surface has been achieved, the surface is or can be coated with a suitable coating to make it impermeable to moisture.

[0061] Alternatively, the energy-absorbing liner blank can be provided as a solid hemispherical form having a convex hemispherical surface and a flat, circular surface with substantially no initial concavity. The operation of the CNC machinery or router to produce the desired inner concave surface of appropriate dimensions based on the digitized headform map proceeds substantially as described in the preceding paragraph, except now the CNC machinery has to grind away a greater volume of material. This embodiment has the advantage that it can be used to accommodate a larger range of head sizes because there is no initial concave inner surface and hence no head that will be too small to use the blank. However, this embodiment also results in a substantial waste of liner material due to the additional wasted material that must be removed to produce the desired inner concave surface for a particular wearer.

[0062] Alternatively, and most preferably, blanks can be provided in a number of predetermined stock sizes, such as small, medium, large, extra-large, etc., where the size notation refers to the initial dimensions of the inner concave surface in the blank. For example, a small blank may have an inner concave surface whose hemispherical circumference is 15 inches. This size may be suitable, e.g., for persons whose mean head circumference is in the range of 16-17 inches. A medium blank may have an inner concave surface whose hemispherical circumference is 16 inches, and may be suitable, e.g., for persons having a mean head circumference in the range of 17-18 inches, and so on. (The numerical values used in this paragraph are for illustrative purposes only).

[0063] The present method has the further advantage that no hood **65** (see **FIG. 8**) need be employed to provide adequate clearance to accommodate comfort foam padding or upholstery because suitable clearance can be achieved using appropriate computer software to modify the digitized headform map once it is in computer-readable form. Specifically, the computer controller can be programmed with suitable software so as to increase the effective radius along the entire surface map to accommodate an extra ¼ inch or ⅛ inch gap, or any other suitable dimension, as may be desirable or preferable to accommodate the installation of comfort fitting foam into the helmet adjacent the finished liner. Furthermore, the software can be programmed so that the increased radius is present only along certain portions of the head surface where comfort fitting foam will be employed, or even so that the clearance radius is different from one location to the next if appropriate. This is a substantial benefit as the hood **65**, when used, can introduce a substantial variable into the production of the headform **60** that may affect its accuracy as a model of the shape and contour of the wearer's head.

[0064] It is contemplated that a kit for making the hardened headforms **60** can be supplied to retail locations where persons may wish to purchase a custom-fitted helmet, and that the other more expensive equipment, scanner, computer equipment, CNC control equipment, CNC machinery, etc., will be maintained at a fixed location to which hardened headforms can be sent by the retail locations once they have been made. Generally, a person seeking a custom-fitted helmet would patronize one of the retail locations, and a technician employed by the retail store would be trained to prepare the headform from the person's head using the kit (one exemplary such kit is described below). Having completed the headform, the technician would permit it to harden or cure, and then send it back to the fixed location where the other equipment is located, for example in a specialized shipping container which may be supplied with the kit. Then, the headform would be used at the fixed location to produce the corresponding custom fitted energy-absorbing liner **90**. This liner either could be shipped back to the retail location, where the person then could select from a variety of helmet shells into which the liner can be installed, or otherwise the liner can be installed into a desirable helmet shell according to the person's specifications based on, e.g., a catalog selection.

[0065] The present invention, including methods and means for producing a precisely fit custom-fit helmet has a number of significant advantages. The custom fit feature allows the retailer to reduce his inventory of helmets and yet achieve a perfect fit for his customers. If a retailer has five different styles with five sizes in each and five different colors, and if he keeps two of each in stock, that is an inventory of 250 helmets. With a custom-fit helmet according to the invention the retailer could display the same five styles, and have a color chip for perhaps as many as ten or more colors. Because there is precise clearance between the inner surface of the energy-absorbing liner and the wearer's head, it is possible to provide a cooling and refreshing flow of air between the helmet and the head. Conventional helmets require thick padding that inhibits the flow of air. There is less padding in a custom-fit helmet according to the present invention for a given exterior helmet shell dimension, and more energy-absorbing foam (the energy-absorbing liner) than is possible with a conventional helmet by virtue of the fact that there is less comfort foam. This thicker energy-absorbing liner leads to a safer helmet. Because the helmet fits snugly, it has less tendency to roll back at high speeds because it is more stable on the head. Also, even with a perfect fit conventional helmet, due to the standardization of the helmet liner typically there is one spot on the head that rubs harder for a particular wearer, where contact between the liner and the head is more intimate, than the rest of the head. Over prolonged use, for example during a long motorcycle ride, this is irritating to the wearer. With a custom-fit helmet according to the invention, there are no such over-tight spots because the liner is fit precisely to the contour of the particular wearer's head.

[0066] The present invention can be used to make an impact energy-absorbing liner having an inner surface substantially conforming to the shape and contour of a particular wearer's head for a variety of different helmets used in different applications. In a preferred embodiment, the helmet for which the liner is made as described herein is a motorcycle helmet. Alternatively, the helmet can be a bicycle helmet, football helmet, hockey helmet, skiing helmet, skydiving helmet, equestrian helmet, kayaking helmet, or other sports helmet, a helmet for medical intervention for persons prone to seizures or unconsciousness (narcolepsy), industrial protection helmet (e.g. for manufacturing and construction workers), aircraft helmet including military airplane and helicopter pilot helmets, etc.

[0067] A kit also is included, which comprises all of the materials needed to make a hardened headform as described herein using the beanie cap **10**. Preferably, the kit includes the resin-impregnated beanie cap **10**, a protective barrier **30** (preferably latex or silicone), protective gloves, waterproof apron and cape to shield the wearer's body, serrated scissors for cutting the hardened headform, a scissor guide (preferably plastic tube or plastic strip), scissor cut resealing means (preferably super glue or stapler), adhesive tape, a level, a ruler, printed casting instructions and optionally an instructional video.

[0068] Thus far, in the foregoing methods a custom-fit helmets is made by first producing a model of a person's head, a headform, (e.g. from a resin-impregnated beanie cap made from elastic material), and then using that headform to mold (or to prepare a mold for) a foam energy-absorbing liner. The resulting liner is custom-fit to the contour of the person's head from which the headform was prepared.

[0069] The approaches described above will work well to produce custom-fit helmets in response to much of the demand for such helmets, probably more than 90% of the anticipated custom-fit helmet market. For one thing, the use of a hardened headform as described above will permit point-of-sale fitting for a helmet, and then sending the headform back to a fixed location where the helmets are manufactured. Once a particular custom-fit helmet is manufactured based on a particular headform, the finished helmet is shipped back to the point-of-sale where it can be picked up by the customer. This method will prove very convenient for most custom-fit helmet customers, who can pick up their helmets at the point-of-sale. It also will permit many point-of-sale shops, who cannot afford the expensive equipment and do not have the expertise to manufacture a custom-fit liner from a liner blank, nonetheless to participate in the custom-fit-helmet market. It is contemplated that for most such shops, the frequency of the demand for custom-fit helmets will not be sufficient to justify the investment in machinery and training necessary to make custom-fit helmet liners on site.

[0070] However, by using a headform to approximate the anticipated wearer's head, there is introduced into the custom fitting process a potentially significant source of error. Namely, the headform may be susceptible to damage, e.g. while in transit from a point-of-sale where it was made to a fixed location where it is to be used to make a custom-fit liner. The use of a headform also may introduce additional unforeseeable variables into the custom fitting process. Consequently, in circumstances where it is practical to have the anticipated wearer and scanning or digitizing equipment present at the same location, a further preferred embodiment involves scanning the person's head directly using the scanning and digitizing equipment, instead of going through a headform as an intermediate. In this method, the scanning equipment obtains information and measurements directly of the person's head to generate the computer-readable data for (digitize) a head contour map as described above. The process proceeds similarly as illustrated in **FIG. 11**, except that the person's head is substituted for the headform **60** illustrated schematically in that figure. It is contemplated this embodiment will be desirable particularly where large scale helmet fitting opportunities exist, for example, 100 people are to be fitted in several days. Specifically, a scanner or other suitable machine (such as a coordinate measuring machine) capable of directly scanning a person's head measures the surface dimensions and contour of the head. If appropriate, contour lines or other notation can be marked on the person's head prior to scanning, which act as reference points for the scanning equipment. Most preferably, the scanning equipment uses lasers to scan the head, and includes or is coupled to a processor that is capable of generating electronic computer-readable data comprising a digitized surface map or solid surface model of the scanned head. This computer-readable data is then fed into or used by a computer controller that is coupled to suitable CNC machinery to control the operation of the machinery, which then produces a custom-fit liner from a liner blank (such as by milling) as already described. As noted, the scanning equipment preferably uses lasers to produce a solid form model from which the computer-readable data is generated. Less preferably, other surface contour mapping equipment, which can be or is coupled to a processor for generating the computer-readable data, can be used, such as machinery using one or a plurality of styluses to measure the head's surface contour mechanically.

[0071] By directly scanning and measuring head shapes and skipping the step of the preparing or using a separate headform, substantial time and cost savings are possible when the wearer and the scanning equipment can be located in the same place. Also, a substantial opportunity for the introduction of error is avoided. There are points that should be kept in mind when scanning and digitizing the head.

[0072] When laser scanning any predominantly round object, the highest fidelity that is achieved is where the angle between the surface and the laser is 90°. Lesser angles may result in lost fidelity. As an example, if the scanning laser is directed at an angle that is 90° to the spine of the person being measured, the best fidelity would be for scanning the circumference of the head, e.g. at the level of the nose, and the worst would be for scanning the top of the head. This is because the laser would be essentially parallel or tangent to the uppermost surface portion of the head, and so would not produce a very accurate contour map of that portion. One way to correct this problem is to use a single laser that is oriented at an angle of 45° to the spine, so that both the circumferential portion and the uppermost surface or crown portion (which is of substantial concerned when fitting an energy-absorbing helmet liner) of the head can be scanned and contour maps generated with a reasonable degree of accuracy. Assuming the laser source is angled at 45° to the spine from a location generally above the head, this will leave the base portion of the head less well defined. However, the base portion is of the least concern when fitting an energy-absorbing liner.

[0073] Alternatively, a plurality of scanning lasers can be used to collect surface contour data, for example one at an angle of 90° to the spine for providing the most accurate contour data for the perimeter of the head, and a second laser at an angle parallel to the spine whose source is located generally above the head to provide the most accurate contour data for the crown portion of the head. Alternatively, in addition to or instead of one of these two lasers, a laser angled at 45° to the spine also can be used. When all three of these lasers are used, very accurate surface contour maps of the head can be generated. When multiple lasers are used, a processor collects all of the data from each of the lasers and executes an algorithm to 'fit' all the data together to construct a solid form model of the head surface, and generate computer-readable data that can be subsequently used, e.g., by CNC machinery to manufacture a custom-fit liner from a liner blank.

[0074] As described above, the computer readable data can be manipulated to add a specified thickness to the digitized head form, to allow room for relatively soft comfort or 'fit' foam to be placed in the head cavity of a resulting custom-fitted liner so the helmet does not fit too tightly and so that there is room for air to circulate between the scalp and the liner. This specified thickness is generally between ⅛" and ¼" as mentioned above.

[0075] It is also desirable that when a head is scanned, an elastic cap or beanie that fits relatively tightly against the wearer's head is worn to provide a more uniform, substantially smoothly contoured target for the laser, and to compress the person's hair uniformly as it would be compressed in a helmet. Once the computer-readable data has been generated, the data can be used similarly as already described to produce or manufacture a custom-fit helmet liner from a liner blank.

[0076] Also as noted, it is possible to directly scan the head using more traditional coordinate measuring machines, such as those employing a mechanical arm or stylus. These machines are slower at scanning but less expensive than the laser scanning devices currently available. Another advantage to laser scanning is that a trained technician using a laser scanner can often provide a better fit by noting head shape and changing the standardized offset distance (to allow for the fit foam) depending upon the head shape. For example, a head that is very flat on the top can get by with tighter tolerances than a head that is more pointed. Thus a pointed head may need ¼" offset where a flat head on top the offset could be more like ⅛".

[0077] It is contemplated that all the scanning, digitizing and milling equipment can be provided or mounted in a mobile platform, for example, in a truck or trailer, or other transportable mode, such that the equipment can be transported conveniently to a place where a large number of helmets are to be produced or have been ordered. For example, a mobile platform such as a trailer containing the equipment could be driven or transported to a military base to fit military pilots for their helmets, or infantry for their combat helmets, or to a sports arena to fit players' helmets. Alternatively, the equipment could be transported to any other location where a relatively large number (to offset the equipment and method costs) of high quality, custom-fitted helmets are to be produced such as trade shows, auto race tracks, or virtually anywhere else.

[0078] Although the hereinabove described embodiments of the invention constitute the preferred embodiments, it will be understood that modifications can be made thereto without departing from the spirit and cope of the invention as set forth in the appended claims.

What is claimed is:

1. A method of making an energy-absorbing liner that is custom-fitted to a wearer's head comprising:

a) directly scanning a person's head and generating computer-readable data comprising a surface map of the person's head;

b) providing a pre-made energy-absorbing liner blank having at least one surface; and

c) machining said at least one surface of said energy-absorbing liner blank, based on said computer-readable data, to provide a convex surface therein whose shape and contour substantially conform to the shape and contour of the person's head.

2. A method according to claim 1, said impact energy-absorbing liner blank comprising viscoelastic foam.

3. A method according to claim 1, said impact energy-absorbing liner blank comprising expanded polystyrene.

4. A method according to claim 1, said impact energy-absorbing liner blank comprising expanded polypropylene.

5. A method according to claim 1, further comprising providing an elastic cap over said person's head prior to scanning the head.

6. A method according to claim 1, said energy-absorbing liner blank being made by molding a foaming composition in a mold, and curing said foaming composition to provide said energy-absorbing liner blank, said liner blank thereby being a foam liner blank.

7. A method according to claim 6, said energy-absorbing foam liner blank comprising viscoelastic foam.

8. A method according to claim 6, said energy-absorbing foam liner blank comprising expanded polystyrene.

9. A method according to claim 6, said energy-absorbing foam liner blank comprising expanded polypropylene.

10. A method according to claim 6, said foaming composition comprising isocyanate and at least one polyol.

11. A method according to claim 1, said person's head being scanned by one or a plurality of lasers to generate said computer-readable data comprising a surface map of said person's head.

12. A method according to claim 11, wherein a first scanning laser is oriented at an angle of 45° to the person's spine from above said person's head.

13. A method according to claim 12, wherein a second scanning laser is oriented either at an angle of 90° to the person's spine or parallel to the person's spine.

14. A method according to claim 11, wherein a first scanning laser is oriented at an angle of 90° to the person's spine and a second scanning laser is oriented parallel to the person's spine.

15. A method according to claim 1, further comprising providing said impact energy-absorbing liner in a motorcycle helmet.

16. A method according to claim 1, further comprising manipulating said computer-readable data to increase an effective radius along at least a portion of the surface map of said person's head in order to provide a predetermined clearance to accommodate the installation of comfort fitting foam into a helmet adjacent a finished energy-absorbing liner made from said liner blank.

17. A method according to claim 1, said energy-absorbing liner blank being machined using CNC machinery, based on said computer-readable data, to provide a finished energy-absorbing liner having said convex surface therein whose shape and contour substantially conform to the shape and contour of said person's head.

18. A method according to claim 17, said CNC machinery comprising a CNC router.

19. A method according to claim 1, said computer-readable data being generated by scanning said person's head using a scanner or a coordinate measuring machine capable of directly scanning the head to measure the surface dimensions and contour thereof.

20. A helmet that is custom-fitted to a particular wearer's head, the helmet comprising an impact energy-absorbing liner made according to the method of claim 1.

21. A helmet that is custom-fitted to a particular wearer's head, the helmet comprising an impact energy-absorbing liner made according to the method of claim 11.

22. A helmet according to claim 21, said energy-absorbing liner comprising viscoelastic foam.

23. A helmet according to claim 21, said energy-absorbing liner comprising semi-rigid viscoelastic foam.

24. A helmet according to claim 21, said energy-absorbing liner comprising expanded polystyrene.

25. A helmet according to claim 23, said foam exhibiting substantially 100% crush recovery following an impact.

26. An apparatus for producing a custom-fitted energy-absorbing liner, comprising means for directly scanning a person's head to generate computer-readable data comprising a surface map of said person's head, and means to machine an impact energy-absorbing liner blank to provide a convex surface therein whose shape and contour substantially conform to the shape and contour of said person's head, both said scanning means and said machining means being provided on a mobile platform.

27. A combination according to claim 26, said mobile platform being a trailer or a truck.

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