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(71) Applicant (for all designated States except US): **LLOYD (SCOTLAND) LIMITED** [GB/GB]; 152 Bath Street, Glasgow G2 4TB (GB).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **SAJIC, Peter** [GB/GB]; 9 Golflinks Road, Broadstone, Dorset BH18 8BE (GB).

(74) Agent: **MURGITROYD & COMPANY**; 165-169 Scotland Street, Glasgow G5 9PL (GB).

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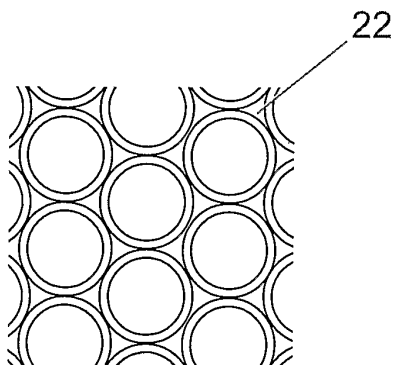
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(54) Title: BODY PROTECTING DEVICE



(57) Abstract: A body protecting device for wearing by a user comprising an array of energy absorbing cells, wherein each cell comprises a tube, and wherein substantially each tube has a side wall which is near or adjacent to the side wall of at least another tube, and wherein substantially each tube is configured such that the orientation of the tube is substantially maintained when a load is applied parallel to the axis of the tube.

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1     Body Protecting Device

2

3     The present invention relates to body protecting  
4     devices. In particular, but not exclusively, the  
5     invention relates to the energy absorbing materials  
6     used in devices having a relatively large curvature  
7     such as safety helmets, elbow pads, knee pads,  
8     shoulder pads and the like, and methods of forming  
9     such materials.

10

11    Many body protecting devices have a large curvature,  
12     $\kappa$ , which is defined as the inverse of the radius of  
13    curvature,  $\rho$ , for the device. The device, such as a  
14    safety helmet, may require a permanently curved  
15    shape. Other devices, such as pads for elbows,  
16    knees and shoulders, may have to be sufficiently  
17    flexible to elastically adopt such a curved shape in  
18    response to movements of the body. Suitable  
19    materials and forming methods must be used for these  
20    devices.

21

1 Crash helmets conventionally comprise a  
2 substantially spheroidal outer skin of tough  
3 plastics material and an inner skin of resilient  
4 material such as a hard foam. The rigid outer skin  
5 transmits an impact load more evenly to the inner  
6 skin which absorbs the energy imparted by the impact  
7 load. The helmets are formed in a female mould, or  
8 around a male mould, and the materials must undergo  
9 significant curvature to form the spheroidal shape.  
10 Also, the outer and inner skins must be inserted  
11 separately to the mould. Otherwise, during bending,  
12 the bond between the two materials would prevent the  
13 necessary slippage of the outer skin (which is  
14 stretched) relative to the inner skin (which is  
15 compressed), or else would produce high planar  
16 stresses at the internal and external surfaces.

17  
18 It may be desirable to decrease the total mass of  
19 the helmet. Also, the methods of forming the  
20 helmets, which typically involve hand lay-up, tend  
21 to be complex and expensive. It would be  
22 advantageous to be able to insert the inner and  
23 outer skin as a one-piece material within the mould.

24  
25 Axially loaded columns of various cross sectional  
26 shapes have been used for some time to improve the  
27 structural crashworthiness of vehicles, roadside  
28 furniture and the like. The columns of each of  
29 these known systems are typically unconnected and  
30 function independently. Regardless of the material  
31 from which the columns are formed, a global buckling  
32 failure mode (or a local failure which leads to

1 failure of the whole column) is to be avoided as  
2 this does not efficiently absorb impact energy.

3

4 It is desirable that metal columns exhibit a  
5 multiple local buckling and folding failure mode  
6 which is effective in absorbing impact energy.  
7 Plastic and composite columns have a number of  
8 failure modes which are efficient for absorbing  
9 impact energy but all of the modes typically involve  
10 progressive crushing of one end of the column.

11

12 The performance and failure mode of plastic and  
13 composite columns depends on a complex interaction  
14 of a number of different parameters including the  
15 material used, the geometry (shape and thickness),  
16 fibre alignment in composites, the use of triggers,  
17 and the loading conditions. However, a careful  
18 selection of these parameters can result in a safety  
19 device which outperforms the metal equivalent.

20

21 Regardless of the material used, arrays of  
22 independent columns arranged parallel to the load  
23 have generally been found to increase energy  
24 absorbing performance and improve the stability of  
25 the safety device. Columns tend to produce a  
26 relatively constant level of energy absorption as  
27 the column is progressively buckled or crushed.  
28 Axially loaded cones have been found to produce a  
29 more linearly increasing rate of energy absorption  
30 which can often be more desirable in crash  
31 situations. However, as the columns are  
32 independent, a localised load can cause an

1     undesirable global failure of columns which have an  
2     axis which is offset from the axis of the applied  
3     load. Also, as the columns are independent, the  
4     columns are formed to be relatively thick to avoid  
5     instability during loading.

6  
7     Sandwich panels, consisting of two tough outer skins  
8     separated by a core material having a lower  
9     stiffness, have been used in many applications such  
10    as building components and structural panels for  
11    road vehicles and aircraft. A popular core consists  
12    of a honeycomb structure, that is an array of cells,  
13    each cell having a hexagonal cross-section.  
14    However, these cells, or cells of other cross-  
15    sections cannot be regarded as connected columns  
16    since each side wall is shared with the neighbouring  
17    cells. If one cell experiences local failure or  
18    instability then this will affect the neighbouring  
19    cells.

20  
21    The axis of each longitudinal member is normal to  
22    the plane of the inner and outer skins and each end  
23    of each longitudinal member is typically bonded to  
24    the respective skin. Therefore, the honeycomb  
25    structure represents an array of cells arranged  
26    parallel to a load which impacts the plane of one of  
27    the outer skins.

28  
29    WO 94/00031 discloses a safety helmet which includes  
30    a honeycomb sandwich structure. Generally, a hand  
31    lay-up method is used. EP 0881064 discloses a  
32    protective element which also has a honeycomb

1 sandwich structure. The document states that the  
2 element may be incorporated within a wide range of  
3 protective clothing which includes helmets.

4

5 US 3877076 discloses a helmet having an array of  
6 tubes. Each of the tubes is spaced apart and  
7 independent from the others.

8

9 US 4534068 also discloses an array of tubes which  
10 are spaced apart. A local crippling failure is  
11 described.

12

13 Honeycomb structures are suitable for applications  
14 involving flat panels or structures with only a  
15 relatively small curvature. However, problems arise  
16 when the material is used in items having a large  
17 curvature.

18

19 Each hexagonal cell of the honeycomb structure has a  
20 rotation symmetry angle of  $n.60^\circ$ . The cell  
21 therefore does not have rotation symmetry about an  
22 angle of  $90^\circ$ . The cell is therefore not  
23 orthotropic, that is it has a different response to  
24 a load applied at a first angle than to a load  
25 applied at a second angle which is applied at  $90^\circ$   
26 from the first angle. When forming a helmet, the  
27 material is bent around a mould about two orthogonal  
28 axis to form the spheroidal shape. Therefore, a  
29 hexagonal structure can create difficulties when  
30 trying to achieve the curvature desired.

31

1 Furthermore, a hexagonal structure is by nature  
2 anticlastic, in that a positive curvature about an  
3 axis results in a negative curvature about an  
4 orthogonal axis (the shape of a saddle illustrates  
5 this phenomenon). This again leads to difficulties  
6 in the forming process.

7

8 Furthermore, there are disadvantages in using a  
9 honeycomb structure for devices such as pads which  
10 must elastically deform to a large curvature. These  
11 disadvantages include the relatively rigid nature of  
12 the structure. A hexagonal element can be  
13 considered to be six flat plates, each of which are  
14 rigidly fixed at each longitudinal edge. It is  
15 known theoretically and empirically that such  
16 elements, and structures produced from these  
17 elements are relatively inflexible. A pad produced  
18 from such a material can tend to feel stiff and less  
19 comfortable. It is desirable that comfort be  
20 improved without any sacrifice in the energy  
21 absorbing capability of the device.

22

23 According to a first aspect of the present invention  
24 there is provided a body protecting device for  
25 wearing by a user comprising:

26 an array of energy absorbing cells, wherein  
27 each cell comprises a tube, and wherein  
28 substantially each tube has a side wall which is  
29 near or adjacent to the side wall of at least  
30 another tube, and wherein substantially each tube is  
31 configured such that the orientation of the tube is

1 substantially maintained when a load is applied  
2 parallel to the axis of the tube.

3

4 The term "tube" is used to denote a hollow structure  
5 having any regular or irregular geometry.

6 Preferably the tube has a cylindrical or conical  
7 structure, most preferably a circular cylindrical or  
8 circular conical structure. The circular tubular  
9 array results in a material which is substantially  
10 isotropic and substantially non-anticlastic.

11

12 Preferably the body protecting device comprises a  
13 safety helmet. Alternatively, the body protecting  
14 device comprises a safety pad.

15

16 Preferably substantially each tube has a side wall  
17 which abuts the side wall of at least another tube.

18 Preferably substantially each tube has a side wall  
19 which is connected to the side wall of at least  
20 another tube.

21

22 Preferably substantially each tube has a side wall  
23 which is connected to the side wall of at least  
24 another tube by an adhesive. Preferably  
25 substantially each tube has a side wall which is  
26 connected to the side wall of at least another tube  
27 substantially along the length of the tube.

28

29 Alternatively, substantially each tube has a side  
30 wall which is welded or fused to the side wall of at  
31 least another tube.

32



1 One or more tubes may be formed from an inner core  
2 comprising a first material and an outer core  
3 comprising a second material. Preferably each of  
4 the first and second material is a polymer.  
5 Preferably the second material has a lower melting  
6 temperature than the first material. Preferably the  
7 first material comprises polyetherimide. Preferably  
8 the second material comprises a blend of  
9 polyetherimide and polyethylene terephthalate.  
10  
11 Preferably substantially each tube is near or  
12 adjacent to at least three other tubes. Preferably  
13 substantially each tube is near or adjacent to six  
14 other tubes.  
15  
16 Preferably each tube has a diameter of between 2 and  
17 8 mm. Preferably each tube has a diameter of about  
18 6 mm.  
19  
20 Preferably the thickness of the side wall of each  
21 tube is less than 0.5 mm. Preferably the thickness  
22 of the side wall of each tube is between 0.1 and 0.3  
23 mm.  
24  
25 Preferably the length of each tube is less than 50  
26 mm. Preferably the length of each tube is between  
27 30 and 40 mm.  
28  
29 Preferably the array of energy absorbing cells is  
30 provided as an integral material. Preferably the  
31 integral material has, or can deform to, a large  
32 curvature.

1  
2 Preferably the integral material comprises  
3 polycarbonate, polypropylene, polyetherimide,  
4 polyethersulphone or polyphenylsulphone. Preferably  
5 the material comprises Tubus Honeycombs<sup>TM</sup>.

6  
7 According to a second aspect of the present  
8 invention there is provided a liner for a body  
9 protecting device for wearing by a user, the liner  
10 comprising:

11 a first material having an array of energy  
12 absorbing cells, wherein each cell comprises a tube,  
13 and wherein substantially each tube has a side wall  
14 which is near or adjacent to the side wall of at  
15 least another tube, and wherein substantially each  
16 tube is configured such that the orientation of the  
17 tube is substantially maintained when a load is  
18 applied parallel to the axis of the tube.

19  
20 Preferably the body protecting device comprises a  
21 safety helmet. Alternatively, the body protecting  
22 device comprises a safety pad.

23  
24 According to a third aspect of the present  
25 invention, there is provided a body protecting  
26 device comprising:

27 a first material bonded to a second material  
28 using an adhesive, wherein the adhesive has a melt  
29 temperature which is lower than the melt temperature  
30 of the first and second material.

31

1 Preferably the body protecting device comprises a  
2 safety helmet. Alternatively, the body protecting  
3 device comprises a safety pad.

4

5 Preferably the first and second materials are in a  
6 softened state at the melt temperature of the  
7 adhesive. This allows thermoforming of the helmet  
8 at the melt temperature of the adhesive, as the  
9 melted bond allows relative movement between the  
10 first and second materials.

11

12 Preferably the first material is one of a  
13 polycarbonate, polypropylene, polyetherimide,  
14 polyethersulphone or polyphenylsulphone material.

15

16 Preferably the second material is a plastics  
17 material, such as polyetherimide. Preferably the  
18 second material is a fibre reinforced plastics  
19 material. Preferably the fibres are made from glass  
20 or carbon.

21

22 Preferably the adhesive is a thermoplastic.  
23 Preferably the adhesive is a polyester based  
24 material.

25

26 Preferably the melt temperature of the adhesive is  
27 less than 180°C. Preferably the melt temperature of  
28 the adhesive is between 120°C and 140°C.

29

30 Preferably the body protecting device is heated  
31 during forming to between 155°C and 160°C.

32

1 Preferably the body protecting device further  
2 comprises a third material and the first material  
3 interposes the second and third materials.  
4 Preferably the first material is bonded to the third  
5 material using the adhesive.

6  
7 Preferably the first material has an array of energy  
8 absorbing cells, each cell comprising a tube.

9  
10 According to a fourth aspect of the present  
11 invention there is provided a method of forming a  
12 body protecting device comprising:

13 bonding a first material to a second material  
14 using an adhesive, wherein the adhesive has a melt  
15 temperature which is lower than the melt temperature  
16 of the first and second material.

17  
18 Preferably the body protecting device comprises a  
19 safety helmet. Alternatively, the body protecting  
20 device comprises a safety pad.

21  
22 Preferably the method includes selecting first and  
23 second materials which are in a softened state at  
24 the melt temperature of the first material.

25  
26 Preferably the method includes heating the body  
27 protecting device during forming to between 155°C  
28 and 160°C.

29  
30 Preferably the method includes bonding the first  
31 material to a third material using the adhesive.

32

1 Preferably the first material has an array of energy  
2 absorbing cells, each cell comprising a tube.

3

4 An embodiment of the present invention will now be  
5 described, by way of example only, with reference to  
6 the accompanying drawings, in which:

7

8 Fig. 1 is a perspective view of a safety helmet in  
9 accordance with the present invention;

10

11 Fig. 2 is a side view of the sandwich panel used to  
12 form the helmet of Fig. 1;

13

14 Fig. 3 is a side view of the sandwich panel of Fig.  
15 2 in a curved state;

16

17 Fig. 4 is a plan view of a known arrangement of  
18 cells used for the core of a sandwich panel.

19

20 Fig. 5 is a plan view of a tubular array of cells  
21 used in the sandwich panel of Fig. 2;

22

23 Fig. 6 is a sectional side view of the tubular array  
24 of Fig. 5 in a curved state;

25

26 Figs. 7a, 7b and 7c are exaggerated plan views of  
27 positions of the tubular array of Fig. 6 which are  
28 compressed, neutral and extended respectively;

29

30 Fig. 8 is a side view of the heating process used  
31 for the sandwich panel of Fig. 2;

32

1 Fig. 9 is a cross sectional side view of a mould  
2 used in conjunction with the sandwich panel of Fig.  
3 2; and

4  
5 Fig. 10 is the sandwich panel of Fig. 2 in a moulded  
6 state.

7  
8 Referring to Figs. 1 to 3, there is shown a body  
9 protecting device in the form of a safety helmet 10.  
10 The helmet 10 is formed using a panel 12 which  
11 comprises a first material or core 20 which is  
12 sandwiched by a second material or outer skin 30 and  
13 a third material or inner skin 50. Each of the  
14 outer 30 and inner 50 skins are bonded to the core  
15 using an adhesive 40.

16  
17 Fig. 3 shows the sandwich panel 12 in a curved  
18 state. In such a state, the material varies  
19 linearly from a state of zero stress (in respect of  
20 the major planes of the panel 12) at the neutral  
21 axis 14 to a state of maximum tensile stress at the  
22 exterior face of the outer skin 30 and a state of  
23 maximum compressive stress at the interior surface  
24 of the inner skin 50. These tensile and compressive  
25 stresses cause tensile and compressive strains  
26 respectively. Therefore, there is slippage between  
27 the outer skin 30 and the core 20 and the inner skin  
28 50 and the core 20 unless this slippage is prevented  
29 by the adhesive 40.

30  
31 A known core structure is a honeycomb or hexagonal  
32 arrangement which is shown in Fig. 4. Each

1 hexagonal cell 60 has a rotation symmetry angle 62,  
2 64 of  $60^\circ$ ,  $120^\circ$  and so on, or in other words of  
3  $n \cdot 60^\circ$ , where  $n$  is an integer. Therefore, the cell  
4 does not have a rotation symmetry angle of  $90^\circ$  and so  
5 the overall material is not orthotropic. Also, the  
6 material will be anticlastic.

7  
8 Furthermore, the honeycomb cells 60 cannot be  
9 regarded as connected columns since each of the six  
10 side walls of each cell 60 is shared with the  
11 neighbouring cells.

12  
13 Fig. 5 shows an array of cells for the core material  
14 20 according to the invention. Each cell comprises  
15 a tube 22. The tubes 22 are arranged in a close  
16 packed array such that the gap between adjacent  
17 tubes is minimised. Each tube has a diameter of 6  
18 mm, a thickness of between 0.1 and 0.3 mm, and a  
19 length of around 35 mm. This results in a  
20 slenderness ratio (the ratio of the length to the  
21 diameter) of between 100 and 350, and an aspect  
22 ratio (the ratio of the diameter to the thickness) of  
23 between 20 and 60. It is to be appreciated that  
24 these values are one or two orders of magnitude  
25 greater than prior art arrangements.

26  
27 The use of these geometric values, particularly the  
28 low thickness used, results in the desirable failure  
29 mode of progressive buckling being achieved, even  
30 when a polymer material is used for the tubes.  
31 Instability, which could lead to a global buckling  
32 failure mode, is avoided since the tubes are

1 connected to, and supported by, adjacent tubes.  
2 Being connected to six other tubes which are  
3 circumferentially spaced around the tube provides  
4 such support in any direction normal to the axis of  
5 the tube. Therefore, the orientation of each tube  
6 (typically parallel to the axis of an applied load)  
7 is substantially maintained during progressive local  
8 buckling caused by the applied load.

9  
10 The tubes may be bonded together using an adhesive.  
11 Another suitable method is to form the tubes from an  
12 inner core of a first material and an outer core of  
13 a second material, the cores being co-extruded. The  
14 second material can be selected to have a lower  
15 melting temperature than the first material.  
16 Typically, a difference of between 15 and 20 degrees  
17 Celsius can be used. During forming, the tubes can  
18 be heated to a temperature between the melting  
19 temperature of the first and second material. This  
20 causes the side walls of the tubes to become welded  
21 or fused together. This method allows easier  
22 forming of shapes and gives better consistency  
23 during forming.

24  
25 It is to be appreciated that the tubes need not be  
26 connected to provide support to each other, or even  
27 be abutting, as long as the tubes are in close  
28 proximity such that they come into contact following  
29 a small amount of deformation.

30  
31 It is known empirically that an apparatus according  
32 to the invention can provide an efficiency of energy



1     absorption of greater than 80% which is a  
2     significantly improvement on prior art devices.

3  
4     Since each tube 22 has an infinite rotation symmetry  
5     angle, the overall tubular array results in a  
6     material which is substantially isotropic and non-  
7     anticlastic. Nevertheless, the tubes could have  
8     cross sections other than circular and still provide  
9     a superior energy absorption provided that each tube  
10    has a side wall which is near to the side wall of  
11    other tubes.

12  
13    Fig. 6 shows the tubular array in a curved state.  
14    As described above, the planar stress and strain at  
15    the neutral axis 14 is zero and so each tube 22  
16    retains its circular shape as shown in Fig. 7a. At  
17    the inner surface 24, the tubes 22 will be  
18    compressed in the direction of the curvature, and  
19    the profile of the tubes at this position is shown  
20    in exaggerated form in Fig. 7b. At the outer  
21    surface 26, the tubes will be elongated in the  
22    direction of curvature and the profile of the tubes  
23    at this position is shown in Fig. 7c.

24  
25    It should be noted that, despite compression and  
26    extension of the tubes 22, the profile of the tubes  
27    22 when averaged through the thickness of the  
28    material 20 will be as found at the neutral axis 14.  
29    Also, if there is curvature about an orthogonal  
30    axis, this will tend to cause compression and  
31    extension in an orthogonal direction, tending to  
32    cause the profile of the tubes 22 at any point

1 through the thickness to be as found at the neutral  
2 axis 14, although the diameter of the tubes 22 will  
3 be reduced at the inner surface 24 and enlarged at  
4 the outer surface 26. The tube will in effect be a  
5 cone which may even improve the energy absorbing  
6 capability of the structure.

7  
8 The helmet is formed using a suitable thermoforming  
9 process. As shown in Fig. 8, the sandwich panel 12  
10 is heated using heaters 70 to a temperature of  
11 between 155°C to 160°C, which is above the melt  
12 temperature of the adhesive 40.

13  
14 The sandwich panel 12 is then transferred to a mould  
15 as shown in Fig. 9. The male portion 72 of the  
16 mould typically has a rubber contacting face and the  
17 female portion 74 is typically constructed from  
18 aluminium. The mould is at ambient temperature and  
19 the transfer of the panel 12 should be effected  
20 quickly, preferably in less than 6 seconds to  
21 minimise cooling of the panel 12. The male part 72  
22 is then driven towards the female part 74 so that  
23 the panel 12 assumes the shape of the mould.

24  
25 Since the panel 12 has been heated to above the melt  
26 temperature of the adhesive, slippage can take place  
27 between the outer skin 30 and the core 20, and  
28 between the inner skin 50 and the core 20. Cooling  
29 of the panel 12 to a temperature below 50°C ensures  
30 that the panel has assumed the curved profile and  
31 the adhesive once again bonds each of the skins 30,  
32 50 to the core 20. The two parts of the mould can

1     now be separated. The curved panel 12 is shown in  
2     Fig. 10.  
3  
4     Various modifications and improvements can be made  
5     without departing from the scope of the present  
6     invention. For instance, the tubes of the array may  
7     be conical and have a cone angle of any angle.  
8  
9

1     **CLAIMS**

2

3     1.    A body protecting device for wearing by a user  
4     comprising an array of energy absorbing cells,  
5     wherein each cell comprises a tube,  
6     and wherein substantially each tube has a side  
7     wall which is near or adjacent to the side wall of  
8     at least another tube,  
9     and wherein substantially each tube is  
10    configured such that the orientation of the tube is  
11    substantially maintained when a load is applied  
12    parallel to the axis of the tube.

13

14    2.    A body protecting device as claimed in Claim 1,  
15    wherein the tube has a cylindrical or conical  
16    structure.

17

18    3.    A body protecting device as claimed in Claim 1  
19    or 2, wherein the body protecting device comprises a  
20    safety helmet.

21

22    4.    A body protecting device as claimed in any  
23    preceding claim, wherein substantially each tube has  
24    a side wall which abuts the side wall of at least  
25    another tube.

26

27    5.    A body protecting device as claimed in any  
28    preceding claim, wherein substantially each tube has  
29    a side wall which is connected to the side wall of  
30    at least another tube.

31

1     6.    A body protecting device as claimed in Claim 5,  
2     wherein substantially each tube has a side wall  
3     which is connected to the side wall of at least  
4     another tube by an adhesive.

5  
6     7.    A body protecting device as claimed in Claim 5  
7     or 6, wherein substantially each tube has a side  
8     wall which is connected to the side wall of at least  
9     another tube substantially along the length of the  
10    tube.

11  
12    8.    A body protecting device as claimed in Claim 5,  
13    wherein substantially each tube has a side wall  
14    which is welded or fused to the side wall of at  
15    least another tube.

16  
17    9.    A body protecting device as claimed in Claim 8,  
18    wherein one or more tubes are formed from an inner  
19    core comprising a first material and an outer core  
20    comprising a second material.

21  
22    10.   A body protecting device as claimed in Claim 9,  
23    wherein the second material has a lower melting  
24    temperature than the first material.

25  
26    11.   A body protecting device as claimed in any  
27    preceding claim, wherein substantially each tube is  
28    near or adjacent to at least three other tubes.

29  
30    12.   A body protecting device as claimed in any  
31    preceding claim, wherein substantially each tube is  
32    near or adjacent to six other tubes.

1  
2 13. A body protecting device as claimed in any  
3 preceding claim, wherein each tube has a diameter of  
4 between 2 and 8 mm.

5  
6 14. A body protecting device as claimed in any  
7 preceding claim, wherein each tube has a diameter of  
8 about 6 mm.

9  
10 15. A body protecting device as claimed in any  
11 preceding claim, wherein the thickness of the side  
12 wall of each tube is less than 0.5 mm.

13  
14 16. A body protecting device as claimed in any  
15 preceding claim, wherein the thickness of the side  
16 wall of each tube is between 0.1 and 0.3 mm.

17  
18 17. A body protecting device as claimed in any  
19 preceding claim, wherein the length of each tube is  
20 less than 50 mm.

21  
22 18. A body protecting device as claimed in any  
23 preceding claim, wherein the length of each tube is  
24 between 30 and 40 mm.

25  
26 19. A body protecting device as claimed in any  
27 preceding claim, wherein the array of energy  
28 absorbing cells is provided as an integral material.

29  
30 20. A liner for a body protecting device for  
31 wearing by a user, the liner comprising:

1           a first material having an array of energy  
2     absorbing cells, wherein each cell comprises a tube,  
3     and wherein substantially each tube has a side wall  
4     which is near or adjacent to the side wall of at  
5     least another tube, and wherein substantially each  
6     tube is configured such that the orientation of the  
7     tube is substantially maintained when a load is  
8     applied parallel to the axis of the tube.

9

10    21. A liner as claimed in Claim 20, wherein the  
11    body protecting device comprises a safety helmet.

12

13    22. According to a third aspect of the present  
14    invention, there is provided a body protecting  
15    device comprising:

16           a first material bonded to a second material  
17     using an adhesive, wherein the adhesive has a melt  
18     temperature which is lower than the melt temperature  
19     of the first and second material.

20

21    23. The body protecting device of Claim 22, wherein  
22    the first and second materials are in a softened  
23    state at the melt temperature of the adhesive.

24

25    24. The body protecting device of Claim 22 or 23,  
26    wherein the first material is one of a  
27    polycarbonate, polypropylene, polyetherimide,  
28    polyethersulphone or polyphenylsulphone material.

29

30    25. The body protecting device of any of Claims 22  
31    to 24, wherein the second material is a plastics  
32    material.

- 1  
2 26. The body protecting device of Claim 25, wherein  
3 the second material is a fibre reinforced plastics  
4 material.  
5
- 6 27. The body protecting device of any of Claims 22  
7 to 26, wherein the adhesive is a thermoplastic.  
8
- 9 28. The body protecting device of Claim 27, wherein  
10 the adhesive is a polyester based material.  
11
- 12 29. The body protecting device of any of Claims 22  
13 to 28, wherein the melt temperature of the adhesive  
14 is less than 180°C.  
15
- 16 30. The body protecting device of Claim 29, wherein  
17 the melt temperature of the adhesive is between  
18 120°C and 140°C.  
19
- 20 31. The body protecting device of Claim 30, wherein  
21 the body protecting device is heated during forming  
22 to between 155°C and 160°C.  
23
- 24 32. The body protecting device of any of Claims 22  
25 to 31, further comprising a third material, wherein  
26 the first material interposes the second and third  
27 materials, and wherein the first material is bonded  
28 to the third material using the adhesive.  
29
- 30 33. The body protecting device of any of Claims 22  
31 to 32, wherein the first material has an array of  
32 energy absorbing cells, each cell comprising a tube.



1

2 34. A method of forming a body protecting device  
3 comprising:

4 bonding a first material to a second material  
5 using an adhesive, wherein the adhesive has a melt  
6 temperature which is lower than the melt temperature  
7 of the first and second material.

8

9 35. The method of Claim 34, including selecting  
10 first and second materials which are in a softened  
11 state at the melt temperature of the first material.

12

13 36. The method of Claim 34 or 35, including heating  
14 the body protecting device during forming to between  
15 155°C and 160°C.

16

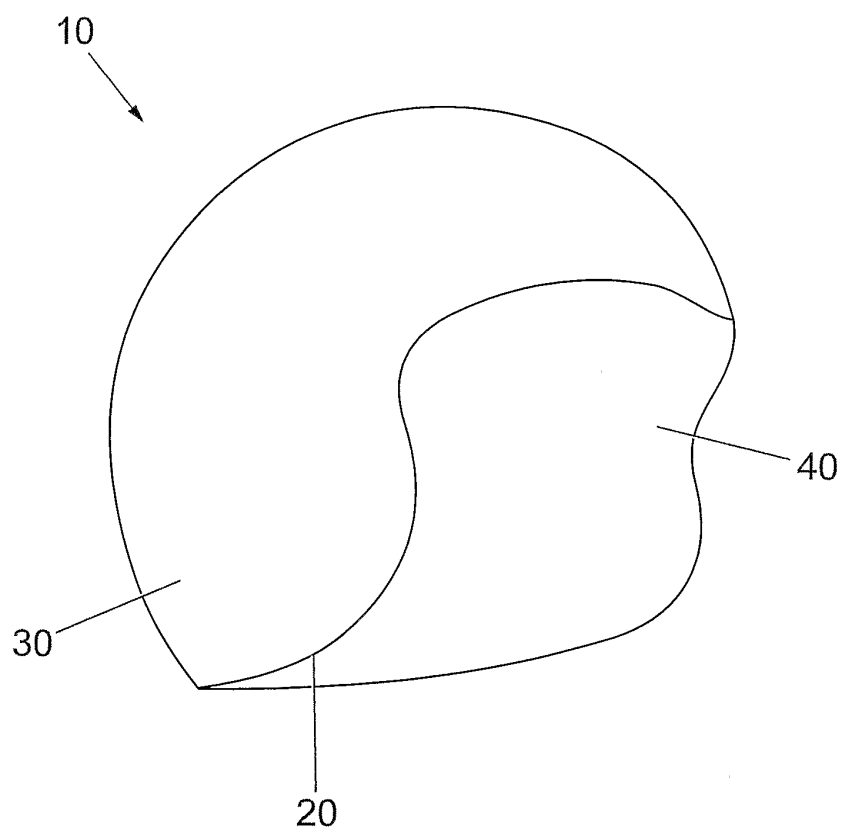
17 37. The method of any of Claims 34 to 36, including  
18 bonding the first material to a third material using  
19 the adhesive.

20

21 38. The method of any of Claims 34 to 37, wherein  
22 the first material has an array of energy absorbing  
23 cells, each cell comprising a tube.

24

1 / 4



*Fig. 1*

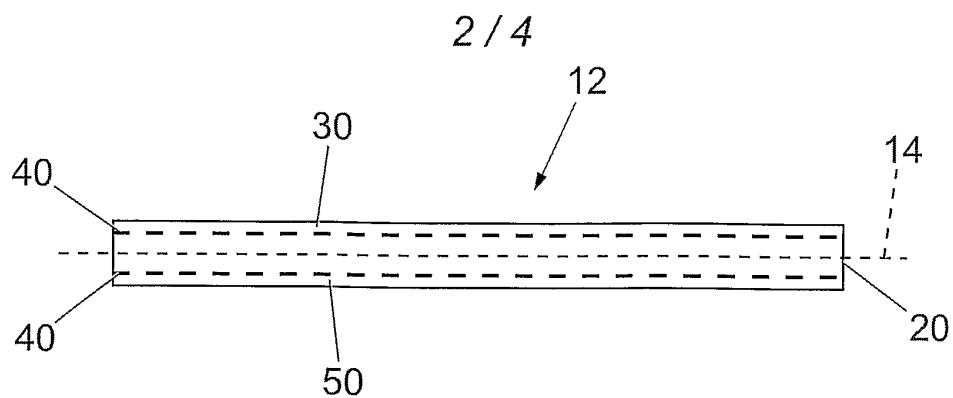


Fig. 2

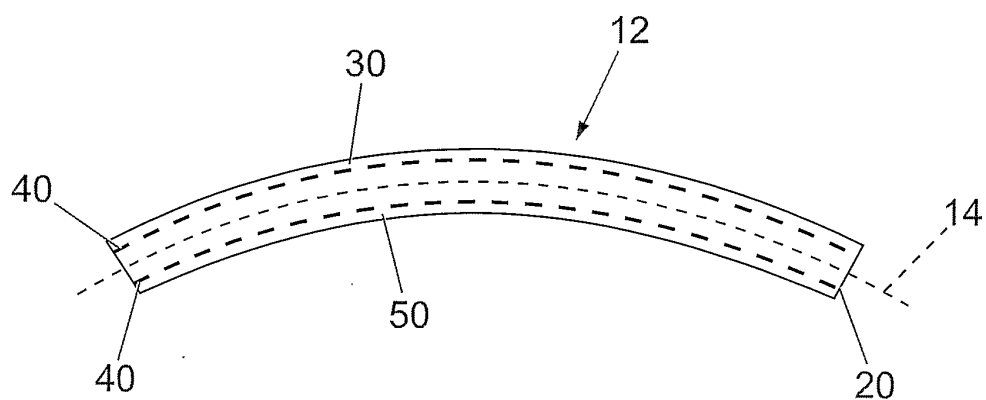


Fig. 3

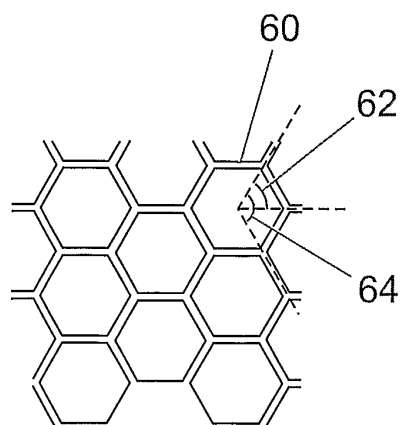


Fig. 4

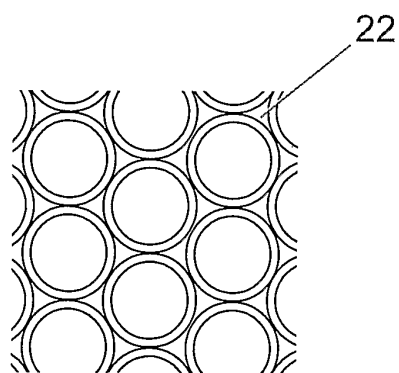
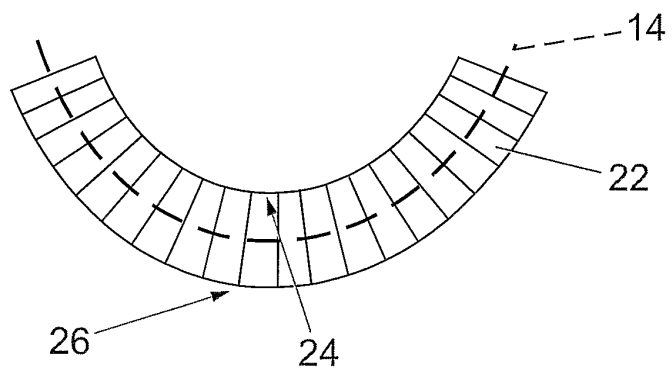
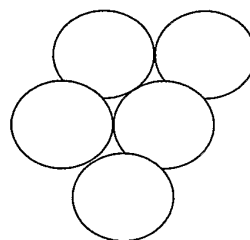


Fig. 5

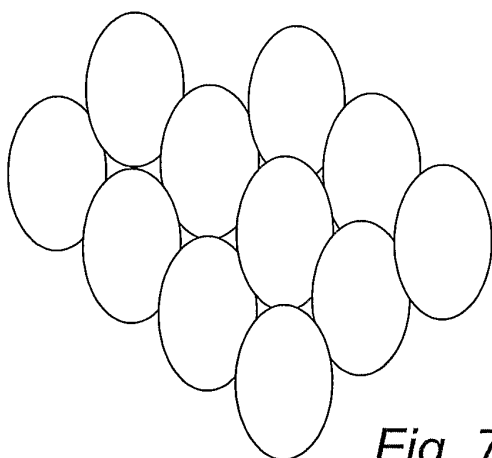
3 / 4



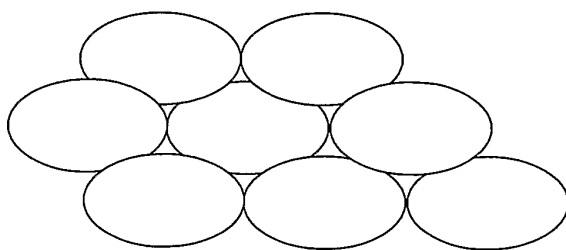
*Fig. 6*



*Fig. 7a*

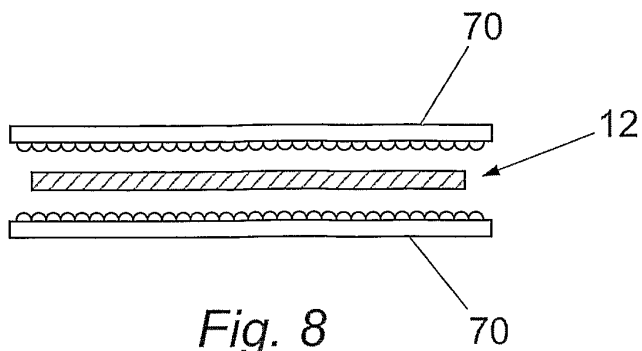


*Fig. 7b*

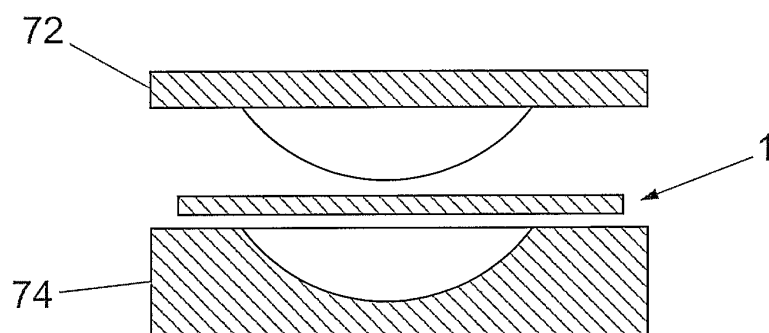


*Fig. 7c*

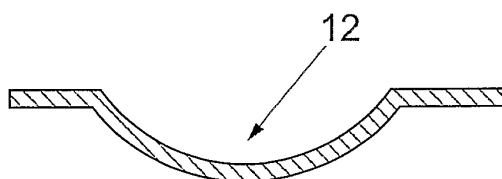
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*Fig. 8*



*Fig. 9*



*Fig. 10*