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(54) **Personal protection equipment**

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Équipement de protection personnelle

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Description

[0001] The present invention relates to personal protection equipment.

[0002] Figure 1 shows the interior of an existing infantry helmet 100. The helmet has an outer shell 102 formed of Kevlar, a foam liner 104 and front 106 and rear 108 foam pads. The outer shell is designed to provide ballistic impact protection, with the foam liner providing a more general "knock" protection layer. The front and rear pads are used for comfort and for holding the helmet in place on the wearer's head.

[0003] Such conventional existing foam liners 104 are of solid construction. Coupled with the front and rear pads 106, 108 the existing liners restrict the circulation of air around the head of the wearer. In hot arid climates and/or during increased workload, lack of air circulation can lead to discomfort, resulting in degradation of performance through factors such as dehydration. In a similar manner, existing ballistic body armour consists of either layers of Kevlar to form a soft jacket, or hard jackets consisting of ceramic plates. As with helmets, these items are close fitting with reduced thermal comfort properties. Many other types of existing non-military protective equipment (which includes clothing), such as sports and workplace (e.g. construction) gear/pads, can also include layers of foam padding that have the same disadvantages.

[0004] DE102006055432A1 discloses a layer adapted for use in personal protective equipment, the layer including a three-dimensional lattice structure. US2010/095557A1 discloses how to build a three-dimensional structure by rapid prototyping and laser sintering of powdered material, in particular components of sports footwear.

[0005] Embodiments of the present invention can address at least some of the problems discussed above.

[0006] According to a first aspect of the present invention, there is provided personal protective equipment including a layer which includes a flexible and/or resilient three-dimensional lattice structure formed of fused powder material, said lattice structure having discrete or continuous internal gaps or spaces for improved air circulation and higher thermal comfort for a user, the personal protective equipment comprising a helmet or an item of body armour.

[0007] The lattice structure is typically flexible and/or resilient. The fused powder material may comprise a polymer, which may be a Tetrapolyurethane, e.g. DuraForm™. At least one further material may be included in the powder material. For example, silver may be included.

[0008] The lattice may be uniform or non-uniform. In some embodiments, the lattice has a square (or triangular) grid topography. In another embodiment the lattice has a form of a spiral wound around an opposed pair of elongate side members. The lattice may take a form of an arrangement of interconnected box-like frames. The lattice may include helical or spiral-like shapes. The lattice may include an arrangement of planar shapes, each planar shape having at least one strut connecting the planar shape to another one of the planar shapes.

[0009] The layer, in use, may be in direct contact with a user of the personal protective equipment.

[0010] An item of personal protective equipment can be provided. In some embodiments, the equipment comprises a helmet and the layer comprises a liner for the helmet. The layer may further comprise a front and/or rear pad for the helmet, the front and/or rear pad having a softer lattice structure than the helmet liner. The front and/or rear pad may be formed integrally with the liner, or may be separate components. In other embodiments, the equipment can comprise body armour.

[0011] According to other aspects of the present invention there are provided items of personal protective equipment substantially as described herein.

[0012] According to yet another aspect of the present invention there is provided a layer adapted for use in personal protection equipment, the layer, in use, being in direct contact with the user.

[0013] According to an alternative aspect of the present invention there is provided a layer adapted for use in personal protection equipment, the layer being formed by an Additive Manufacturing process and including an arrangement of internal spaces.

[0014] According to a further aspect of the invention there is provided a method of forming a personal protective equipment layer (substantially as described herein), the method including:

providing the material in powder form, and
using an Additive Manufacturing technique to fuse the powder to form the layer.

[0015] The Additive Manufacturing technique may comprise Selective Laser Sintering.

[0016] Whilst the invention has been described above, it extends to any inventive combination of features set out above or in the following description. Although illustrative embodiments of the invention are described in detail herein with reference to the accompanying drawings, it is to be understood that the invention is not limited to these precise embodiments. As such, many modifications and variations will be apparent to the practitioners skilled in the art. Furthermore, it is contemplated that a particular feature described either individually or as part of an embodiment can be combined with other individually described features, or parts or other embodiments, even if the other features and embodiments make no mention of the particular feature. Thus, the invention extends to such specific combinations not already discussed.

[0017] The invention may be performed in various ways, and, by way of example only, an embodiment thereof will now be described, reference being made to the accompanying drawings in which:

Figure 1 shows the inside of a conventional protective helmet;

Figure 2 is a flowchart showing steps involved in producing a helmet liner according to an embodiment of the present invention;

Figures 3A - 3D show example helmet liners;

Figure 4 is a graph showing load displacement characteristics for the example liners of Figures 3A - 3D, and

Figure 5 shows the inside of a helmet fitted with an example liner.

[0018] Figure 2 shows an example of a method used to form a layer for use in personal protective equipment. The method involves the known additive manufacture technique of Selective Laser Sintering (SLS). The SLS process builds components layer-by-layer using a high-temperature laser to fuse particles of powder material together. The process begins with an initial bed of powder material maintained at an ambient temperature a few degrees below the melting point of the material. A high-temperature laser is then used to scan a cross-sectional slice of the component, in the x-y plane, causing the powder to locally fuse together. The component is then built up incrementally in the z plane, by adding and scanning additional layers of powder (typically 100μm thick), until the entire component has been constructed. Finally, excess powder can be removed from the completed component and may be recycled. The SLS process is similar in nature to other rapid prototyping techniques, such as Stereolithography, but has the advantage of being able to build complex geometries without the need for additional support structures, as the un-sintered material at lower levels is capable of supporting material above it. However, in other embodiments, it may be possible to use alternative additive manufacturing techniques, provided suitable preparations are made to the apparatus.

[0019] At step 202, a suitable powder material for forming the layer is provided for SLS processing apparatus (e.g. a 3D Systems Sinter-station 2500). Key attributes for a suitable layer material include low density, high values of elongation to failure, and low tensile modulus, in order to provide good flexibility without the generation of significant stress. The material ideally requires rubber-like flexibility and long-term stability. After investigation, the inventors found that DuraForm™ Flex1 (available from 3D Systems of Rock Hill, SC, USA), a Tetrapolyurethane material exhibiting rubber-like flexibility and long-term stability, to be a suitable plastic material. This material is fully recyclable (i.e. un-sintered material could be reprocessed) nature of the material and the ability to add infiltrants to finish components and alter their mechanical properties can provide significant material benefits. Further information on use of this material in SLS processing can be found in Levy, G.N., Boehler, P., 2005, Controlled local properties in the same part with sintaflex: a new elastomer powder for the sls process, Proc. SFF Symp., Austin: 197-207. It is possible to alter the mechanical properties of the resulting structure by a variety of manufacturing parameters and these can be tuned for a particular application (e.g. the stiffness of a structure can be altered during the build process to give non-uniform properties).

[0020] In some cases at least one further material may be added to the powder. For example, a small proportion of silver may be added for its anti-bacterial properties.

[0021] At step 204, the SLS apparatus is provided with data for producing a suitable design (as known to the skilled person) of a layer for use in personal protection equipment and the apparatus is operated to form such a structure using the material provided at step 202 in a substantially conventional manner.

[0022] Figures 3A - 3D show examples of helmet liner designs. Each of the liners has a curved shape intended to generally match the contours of the top of the wearer's head, but the surface and internal shape of the four example structures differ. Existing helmet liner geometry can be used as a template to ensure a good fit within the helmet. Alternatively, it is possible to custom-make liners (or any other wearable layers produced using the method) to fit an individual's head size/shape (or other body parts).

[0023] In Figure 3A, the structure 300A is formed of interconnected cuboids/boxes in a grid pattern. Although the shapes that make up the structure can be thought of as an arrangement of box-like frames 302 connected together, it will be appreciated that all the example structures are formed as one piece from fused powder. In Figure 3B, the structure 300B is formed of interconnected cuboids/boxes in a similar grid pattern, except that there is a diagonal strut 304 between one set of opposed corners, which form triangular shapes. In Figure 3C, the structure 300C comprises sets of helixes/spirals 306 arranged in a side-by-side manner. In Figure 3D, the structure 300D comprises an arrangement of discs 308 (although it will be appreciated that another planar shape could be used). Each disc has a set of struts 310 extending downwardly from its lower surface to connect with the upper surfaces of discs beneath. It will be appreciated that the illustrated structures are exemplary only and many variations are possible. In general, the structure will comprise a type of lattice having (discrete or continuous) internal gaps/spaces.

[0024] Figure 4 is a graph showing load displacement characteristics for the four lattice designs of Figures 3A - 3D, when subjected to uniaxial compression. The graph shows that the lattice designs range in stiffness, with the cubic design of Figure 3A exhibiting the greatest compression stiffness, and the helix design of Figure 3C showing the least stiffness in compression. All designs exhibited stiffness within the range of the existing foam material used for helmet liners/pads.

[0025] At step 206, the formed layer is removed from the SLS apparatus and used in the construction of the personal safety equipment. In the case where the layer forms a liner for a helmet, the liner is fixed to the inside of the helmet by any suitable means, e.g. adhesives or straps. Figure 5 shows an example helmet 500 with a layer 502 fitted inside it. In use, the layer can be in direct contact with the top of the user's head, although in other applications at least one other layer may be located between the user and the layer. The helmet further includes front 504 and rear 506 pads. In alternative embodiments, the layer 502 can be formed to include integral front and/or rear pad regions that are designed to remove the requirement for separate front and/or rear pads. For example, the layer can have thicker portions at the front/rear pad regions, or these regions may have a different, e.g. softer, form of lattice to the rest of the layer to provide improved impact absorption and better air flow circulation for comfort. Alternatively, the pads may be manufactured using the materials and techniques discussed above, independently of the rest of the liner. Front pads tend to wear more quickly and so this arrangement allows them to be replaced separately from other helmet components.

[0026] The example liners have been tested for the energy absorption characteristics and the results were compared with those for existing foam helmet liners. A standardised shock absorption test was proposed as a suitable method for comparing liner performance. In the UK, British Standard BS6658:1985 is used for the specification of protective helmets for vehicle users and it was used as a basis for the comparative tests. A single crown shock impact test was performed for two samples of each of the lattice liner designs and two of the existing foam liners. In each test the existing front and rear pads were used to aid in the mounting of the helmet to the test headform. For each test the acceleration-time profile was recorded from which the peak acceleration and Head Injury Criteria (HIC) values were taken as a metric for comparing liner performance. The results were provided in the form of acceleration time curves for the four lattice liners. All of the curves exhibited a double peak profile. Each of the lattice liners exhibited a lower initial peak acceleration compared to the existing foam design. The HIC values for all the liners were comparable.

[0027] The helmet liners described above can have advantages in terms of reduced overall weight of the helmet, which can be particularly beneficial when equipment is mounted on the helmet. The use of the material and the processes described above provides a greater level of control over the existing foam method, which produces uniform components. The use of lattice structures provides a greater level of air circulation and therefore higher thermal comfort than can be achieved with the existing solid designs.

[0028] Although the examples discussed above relate to military helmet liners, it will be understood that the techniques can be used to form liners for other types of helmets, e.g. for work, sports or for use on vehicles, such as cycles or motorbikes. It will also be understood that the techniques described herein can be used to form layers for use in items of personal protection equipment other than helmets. The design and manufacturing flexibility allows the structures having any desired shape/dimensions to be produced. For instance, the layers may be used as padding in sports wear, including pads for sports such as cricket, hockey, American football, and so on. The layers could also be used in protective padding/clothing for heavy-duty/dangerous work, such as welding. Further, the layers can be used in body armour equipment.

Claims

1. Personal protective equipment (500) including a layer (502) which includes a flexible and/or resilient three-dimensional lattice structure formed of fused powder material, said lattice structure having discrete or continuous internal gaps or spaces for improved air circulation and higher thermal comfort for a user, the personal protective equipment is a helmet or an item of body armour.

2. Personal protective equipment according to claim 1 in which the said layer is positioned to be worn in direct contact with a user.

3. Personal protective equipment according to claim 1 or 2, wherein the fused powder material provides rubber-like flexibility.

4. Personal protective equipment according to any preceding claim, wherein the lattice takes a form of an arrangement of interconnected box-like frames.

5. Personal protective equipment according to any of claims 1 to 3, wherein the lattice includes helical or spiral-like shapes.

6. Personal protective equipment according to any of claims 1 to 3, wherein the lattice includes an arrangement of planar shapes, each planar shape having at least one strut connecting the planar shape to another one of the planar shapes.

7. Personal protective equipment according to any preceding claim, wherein the equipment comprises a helmet (500) and the layer comprises a liner (502) for the helmet.

8. Personal protective equipment according to claim 7, wherein the layer (502) includes a front and/or rear pad, the said pad having a different lattice structure from other portions of the liner (502).

9. Personal protective equipment according to claim 8, wherein the front and/or rear pad comprises a softer

lattice structure than the liner.

10. Personal protective equipment according to claim 8 or 9, wherein the front and/or rear pad comprises a layer separate from the liner.

11. Personal protective equipment according to any preceding claim, wherein the equipment comprises body armour.

12. Personal protective equipment according to any preceding claim, wherein the equipment comprises padding for sportswear.

13. A method of forming a personal protective equipment according to any one of claims 1 to 12, the method including:

providing (202) the material in powder form, and using (204) an Additive Manufacturing technique to fuse the material to form the layer.

14. A method according to claim 13, wherein the Additive Manufacturing technique comprises Selective Laser Sintering.

15. A method according to claim 13 or 14, in which the stiffness of the structure of the layer is altered during the forming process to give non-uniform properties to the layer.

Patentansprüche

1. Persönliche Schutzausrüstung (500), die eine Schicht (502) beinhaltet, die eine flexible und/oder elastische dreidimensionale Gitterstruktur beinhaltet, die aus verschmolzenem Pulvermaterial gebildet ist, wobei die Gitterstruktur diskrete und kontinuierliche interne Spalte oder Räume für eine verbesserte Luftzirkulation und höheren Wärmekomfort für einen Benutzer aufweist, wobei die persönliche Schutzausrüstung ein Helm oder ein Gegenstand einer Körperpanzerung ist.

2. Persönliche Schutzausrüstung nach Anspruch 1, bei der die Schicht so positioniert ist, dass sie in direktem Kontakt mit einem Benutzer getragen wird.

3. Persönliche Schutzausrüstung nach Anspruch 1 oder 2, wobei das verschmolzene Pulvermaterial eine gummiartige Flexibilität bereitstellt.

4. Persönliche Schutzausrüstung nach einem der vorhergehenden Ansprüche, wobei das Gitter die Form einer Anordnung von miteinander verbundenen kastenartigen Rahmen annimmt.

5. Persönliche Schutzausrüstung nach einem der Ansprüche 1 bis 3, wobei das Gitter helikale oder spiralartige Formen beinhaltet.

6. Persönliche Schutzausrüstung nach einem der Ansprüche 1 bis 3, wobei das Gitter eine Anordnung von ebenflächigen Formen beinhaltet, wobei jede ebenflächige Form wenigstens eine Strebe aufweist, die die ebenflächige Form mit einer anderen der ebenflächigen Formen verbindet.

7. Persönliche Schutzausrüstung nach einem der vorhergehenden Ansprüche, wobei die Ausrüstung einen Helm (500) umfasst und die Schicht eine Auskleidung (502) für den Helm umfasst.

8. Persönliche Schutzausrüstung nach Anspruch 7, wobei die Schicht (502) ein vorderes und/oder hinteres Polster beinhaltet, wobei das Polster eine von anderen Teilen der Auskleidung (502) verschiedene Gitterstruktur aufweist.

9. Persönliche Schutzausrüstung nach Anspruch 8, wobei das vordere und/oder hintere Polster eine weichere Gitterstruktur als die Auskleidung umfasst.

10. Persönliche Schutzausrüstung nach Anspruch 8 oder 9, wobei das vordere und/oder hintere Polster eine von der Auskleidung getrennte Schicht umfasst.

11. Persönliche Schutzausrüstung nach einem der vorhergehenden Ansprüche, wobei die Ausrüstung eine Körperpanzerung umfasst.

12. Persönliche Schutzausrüstung nach einem der vorhergehenden Ansprüche, wobei die Ausrüstung eine Polsterung für Sportbekleidung umfasst.

13. Verfahren zum Bilden einer persönlichen Schutzausrüstung nach einem der Ansprüche 1 bis 12, wobei das Verfahren Folgendes beinhaltet:

Bereitstellen (202) des Materials in Pulverform, und
Verwenden (204) einer additiven Fertigungstechnik, um das Material zum Bilden der Schicht zu verschmelzen.

14. Verfahren nach Anspruch 13, wobei die additive Fertigungstechnik selektives Lasersintern umfasst.

15. Verfahren nach Anspruch 13 oder 14, bei dem die Steifigkeit der Struktur der Schicht während des Bildungsprozesses verändert wird, um der Schicht nichteinheitliche Eigenschaften zu verleihen.

Revendications

1. Equipement de protection personnel (500) comportant une couche (502) qui comporte une structure en treillis tridimensionnelle flexible et/ou résiliente formée d'un matériau en poudre fusionné, ladite structure en treillis ayant des écartements ou espaces internes discrets ou continus pour une circulation d'air améliorée et un plus grand confort thermique pour un utilisateur, l'équipement de protection personnel est un casque ou un article d'armure.

2. Equipement de protection personnel selon la revendication 1, dans lequel ladite couche est positionnée pour être portée en contact direct avec un utilisateur.

3. Equipement de protection personnel selon la revendication 1 ou 2, dans lequel le matériau en poudre fusionné confère une flexibilité de type caoutchouc.

4. Equipement de protection personnel selon l'une quelconque des revendications précédentes, dans lequel le treillis prend une forme d'un agencement d'armatures de type boîte reliées.

5. Equipement de protection personnel selon l'une quelconque des revendications 1 à 3, dans lequel le treillis comporte des formes de type hélicoïdal ou en spirale.

6. Equipement de protection personnel selon l'une quelconque des revendications 1 à 3, dans lequel le treillis comporte un agencement de formes planes, chaque forme plane ayant au moins un étrésillon raccordant la forme plane à une autre des formes planes.

7. Equipement de protection personnel selon l'une quelconque des revendications précédentes, dans lequel l'équipement comprend un casque (500) et la couche comprend une doublure (502) pour le casque.

8. Equipement de protection personnel selon la revendication 7, dans lequel la couche (502) comporte un coussinet avant et/ou arrière, ledit coussinet ayant une structure en treillis différente d'autres portions de la doublure (502).

9. Equipement de protection personnel selon la revendication 8, dans lequel le coussinet avant et/ou arrière comprend une structure en treillis plus souple que la doublure.

10. Equipement de protection personnel selon la revendication 8 ou 9, dans lequel le coussinet avant et/ou arrière comprend une couche séparée de la doublure.

11. Equipement de protection personnel selon l'une quelconque des revendications précédentes, dans lequel l'équipement comprend une armure.

12. Equipement de protection personnel selon l'une quelconque des revendications précédentes, dans lequel l'équipement comprend un rembourrage pour un vêtement de sport.

13. Procédé de formation d'un équipement de protection personnel selon l'une quelconque des revendications 1 à 12, le procédé comportant :

    la fourniture (202) du matériau sous forme de poudre, et
    l'utilisation (204) d'une technique de fabrication additive pour fusionner le matériau afin de former la couche.

14. Procédé selon la revendication 13, dans lequel la technique de fabrication additive comprend le frittage sélectif au laser.

15. Procédé selon la revendication 13 ou 14, dans lequel la raideur de la structure de la couche est modifiée pendant le processus de formation pour donner des propriétés non uniformes à la couche.

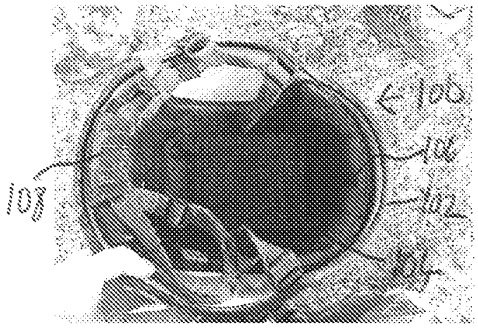


FIG. 1

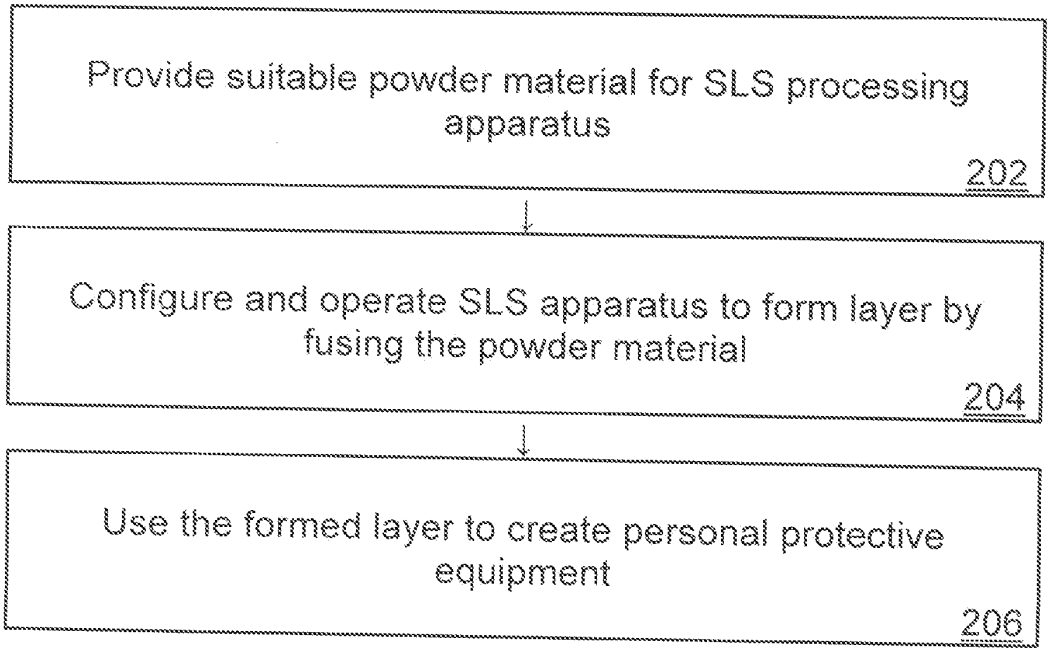


FIG. 2

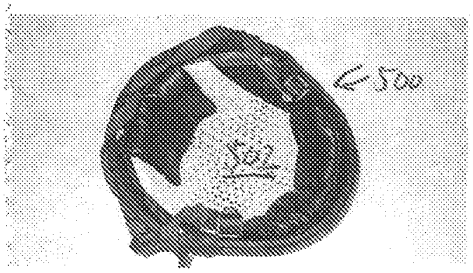


FIG. 5

FIG. 3A

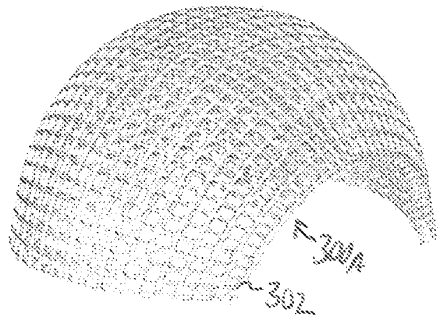


FIG. 3C

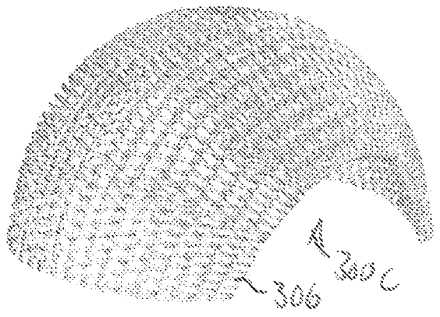


FIG. 3B

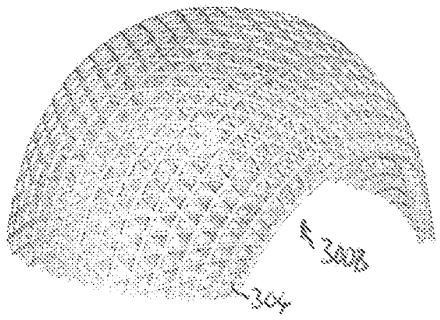
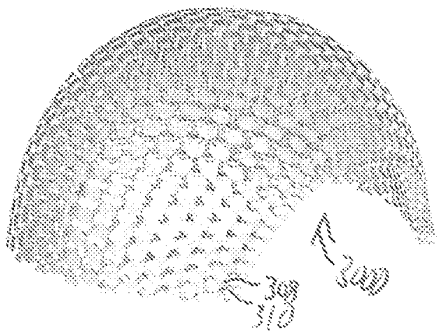


FIG. 3D



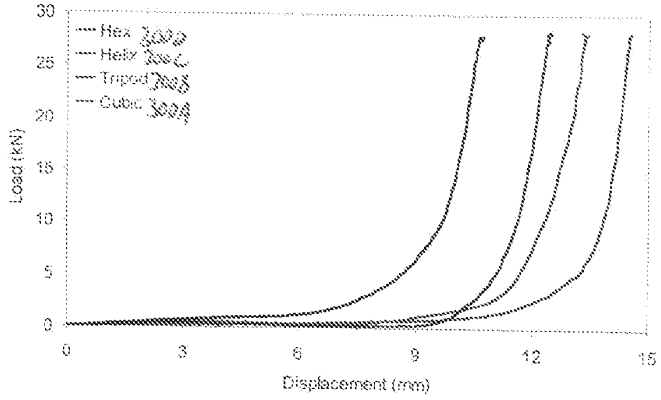


FIG. 4

REFERENCES CITED IN THE DESCRIPTION

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