(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 878 993 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
16.01.2008 Bulletin 2008/03

(51) Int Cl.:
F41H 5/04 *(2006.01)*

(21) Application number: **07252773.2**

(22) Date of filing: **11.07.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK YU

(30) Priority: **11.07.2006 GB 0613764**

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(54) **Ceramic or metal tile armour**

(57) A hard faced, e.g. ceramic, armour tile comprises an array of sub-tiles (2) formed by narrow slots (1). Edges of the slots may be chamfered asymmetrically. The tiles may be combined in layers and held together by a moulding material.

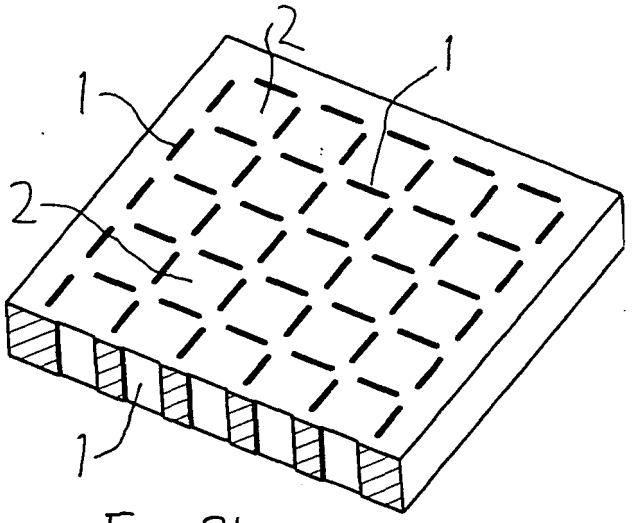

Fig. 2b

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Description

[0001] This invention relates to armour, for example ceramic armour formed from a plurality of tiles.

[0002] Armour-piercing bullets normally consist of a very hard penetrating core covered in a softer jacket that engages with the rifling of the gun during firing and provides an aerodynamic outer shape for low drag and high accuracy. The penetrating core, sometimes simply referred to as the penetrator or the core, is normally designed with a sharp point so as to focus the kinetic energy of the projectile on a very small area of the front face of the armour during impact. Known armour seeks to dissipate this kinetic energy with minimum armour damage and without allowing penetration of the threat projectile or dislodged armour fragments through the armour system into a protected region.

[0003] Ceramic armour is often used in view of its reduced weight as compared to metallic armour. Figure 1 shows known ceramic armour constructed in two layers in accordance with the "disturber-absorber" principle, whereby a hard front face 11 is used to "disturb" the normal operation of an armour-piercing bullet 12 and a backing layer 13 of composite materials and/or air gaps and/or metallic materials is used to "absorb" the residual effects of the disturbed core and any fragments dislodged from the disturber layer.

[0004] The ceramic disturber layer 11 is selected to have high hardness when compared to that of an armour-piercing core. This enables it to blunt and/or fracture the core during impact, significantly reducing its penetrating ability. A conoid 14 of fractured ceramic, sometimes termed a "conoid of rubble", also forms in the ceramic layer 1 with the point of impact at its apex. The formation of this conoid absorbs kinetic energy from the core, following which the conoid 14 itself tends to dissipate the core's remaining kinetic energy over a larger area as it tries to continue forward, decelerating as it works its way through the "rubble". The penetrating ability of a blunted and/or fractured core is still considerable and the conoid of fractured ceramic will be pushed forward by the disturbed core at quite high velocity if it is not held in place. This necessitates the presence of an absorber layer 13 behind the ceramic, to prevent any ceramic fragments breaking free and to absorb the remaining kinetic energy in the disturbed core. In many instances, this energy absorption is accompanied by permanent, plastic deformation of the absorber layer.

[0005] Ceramic armour such as that shown in Figure 1 is normally in the form of an array of close-fitting tiles which are polygonal, e.g. square or hexagonal. An impact on a tile will cause local damage around the impact point as well as initiating cracks which can propagate over long distances as far as the edge of the tile, but not into adjacent tiles. These cracks may result in sections of the ceramic layer becoming loose and falling away, or reduce the tile's ability to withstand further bullet strikes due to pre-existing damage. Therefore, for multi-hit capability the surface area of any one tile should be small to limit the extent of surface damage caused by the impact of a single projectile.

[0006] However, minimum tile size is normally governed by the need to spread the kinetic energy of the bullet over a large area of the absorber layer. In addition, large arrays of small tiles can be very expensive in terms of the time taken to lay out and properly align the tile array, when compared to the application of small numbers of large tiles.

[0007] It is an aim of the invention to provide a large hard faced, e.g. ceramic tile with strike damage and bullet disrupting features and with enhanced multi-hit performance whilst retaining the low manufacturing cost and simplicity associated with larger ceramic armour tiles.

[0008] The invention provides a hard faced armour tile comprising an array of sub-tiles formed by narrow slots.

[0009] The slots tend to be in the path of and terminate any cracks propagating from an impact point and thus increase the multi-hit performance compared to traditional large ceramic tiles.

[0010] The sub-tiles may be square or hexagonal or of more than one shape. In the case of square sub-tiles the slots can be straight and elongate, L-shaped or cross-shaped.

[0011] The tile can be curved in order to protect a region or object of a given shape.

[0012] In order to destabilise a bullet core, a chamfer or curved transition zone can be formed between an internal surface of each slot and the front surface of the tile. The slot may be asymmetric with the chamfer on one side of the slot at a different angle to the other side. Such chamfers or zones can form a groove around each slot, and in an embodiment of the invention the grooves intersect with each other. To fully control the location of fractures caused by bending moments in the tile, such slots and or/grooves can be formed on a rear surface as well as a front surface of the hard layer.

[0013] The tile may be of ceramic material or another hard material such as a metal matrix composite material.

[0014] The invention also provides armour comprising a plurality of tiles as defined above in layers and a moulding material holding the tiles together. The moulding material flows through the slots and, where the grooves are provided, along the grooves from one slot to another. The moulding material may be metallic or comprise a polymeric resin. In one embodiment, the tiles are stitched together using fibrous material passing through the slots. An absorber layer may be provided or where the thickness of the moulding is sufficient the armour may function as a disturber-absorber system by itself.

[0015] Specific embodiments of the invention will now be described in more detail, by way of example only, with reference to the accompanying drawings, in which:

[0016] Figure 1 shows the known armour already discussed;

[0017] Figures 2a and 2b are a front view and a cut-away view respectively of a tile according to the invention;

[0018] Figures 3a and 3b are a front view and a cut-away view respectively of an alternative tile according to the invention;

[0019] Figures 4a and 4b are a front view and a perspective view respectively of another alternative tile;

[0020] Figures 5a and 5b are a front view and a cut-away view respectively of yet another alternative tile;

[0021] Figures 6a and 6b are a perspective view and a sectional view respectively of a curved tile according to the invention;

[0022] Figure 7 shows a tile with a chamfered slot;

[0023] Figure 8 shows a tile with a curved-edge slot;

[0024] Figures 9a and 9b are a front view and a perspective view respectively of another alternative tile according to the invention;

[0025] Figures 10a to 10c show symmetrical and asymmetrical broken edge slot geometries;

[0026] Figures 11a to 11c are a front view and two perspective views respectively of a tile according to the invention;

[0027] Figures 12a to 12c are a front view and two perspective views respectively of another tile according to the invention; and

[0028] Figure 13 shows two tiles, each according to Figures 12a to 12c, with an added reinforcement.

[0029] Figure 2a shows a ceramic tile having a plurality of through slots 1 arranged so as to divide the tile into square sub-tiles 2 with half the slots horizontal and half vertical. Figure 2b is a view of the tile cut-away along line A-A.

[0030] Figure 3a shows an alternative tile in which the majority of the slots 3 are L-shaped, slots 1*'* at the edge of the array being straight. Figure 3b is a view of the tile cut-away along line B-B.

[0031] Figures 4a and 4b show a tile formed from hexagonal sub-tiles 4, defined by straight slots 5. A plurality of such tiles will tessellate when fitted together.

[0032] Figure 5a shows an embodiment of tile comprising an array of cross-shaped slots 6. Figure 5b is a view of the tile cut-away along line C-C.

[0033] The tile design may need to adapt in terms of edge profile or surface curvature to match the geometry of the three-dimensional region it is intended to protect and the approach direction of the threat bullets. In this regard, Figures 6a and 6b show a curved tile.

[0034] Figure 7 shows an embodiment of slot which is designed to reduce the potential weakness caused by the truncation of the conoid of rubble and to destabilise or tilt the bullet core. The edge of the slot is chamfered at 7. The projectile 8 impacts a surface at an angle less than 90° to the projectile axis. This causes a partial ricochet or tilting due to the off-axis impact force on the nose of the projectile. Figure 8 shows a curved-edge slot which achieves the same effect.

[0035] Figures 9a and 9b show a tile having the slots of Figure 7. The chamfers 7 form grooves surrounding the slots 5'.

[0036] Figure 10a shows that when the axis of the bullet 8 precisely aligns with the axis of the slot 5', the bullet 8 is equally supported whilst aiming directly at the ceramic-free weak spot between the sub-tiles. To prevent such a coincidence the chamfer 7' can be made asymmetric as shown in Figures 10b and 10c. Thus, if the impact forces are balanced, the bullet path is not aligned with the slot, as shown in Figure 10b, or if the bullet and slot axes are aligned, the forces are unbalanced and the bullet is destabilised, as shown by the arrows in Figure 10c.

[0037] Figures 11a to 11c show a tile in which grooves 7' around the slot intersect above the fused regions between the sub-tiles. This controls the location of fractures caused by bending moments induced across the tile. To fully control the location of any bending-moment-induced-fractures, the intersecting grooves 7' are also formed below the slots. Any bending-moment-induced-through-thickness fractures will then tend to occur in the fused regions between sub-tiles. In addition, cracks tending to propagate from an impacted sub-tile directly through a fused region into an adjacent sub-tile will be diverted. On meeting a groove the crack will tend to grow along the line of the groove until it meets with the end of a slot.

[0038] Following a ballistic attack compound ceramic tiles such as those described above could be left in a state where individual sub-tiles have broken away from the body of the main compound tile. These loose sub-tiles could easily be lost from the system if provision was not made to hold them in place. To ensure that the integrity of the compound-tile-based disturber is maintained following a bullet strike, a number of the tiles can be arranged close together and moulded into a single ceramic armour package. Composite wrapping of ceramic armour tile packs is known, but the slots of the tiles of the invention enable the moulding material to pass through the compound tile linking the front of the moulding to the rear in a multitude of positions across the surface of the package. Additionally, the grooves 7, 7', enable the moulding material to flow easily between the slots, thereby increasing the integrity of the moulded wrapping, even with a thin or partial moulded covering at front and rear. Producing such a package in a moulding with a substantial layer of resin and/ or reinforcement on the front and rear can further enhance the integrity of the overall package.

[0039] The moulding can be produced using any feasible moulding technique with a metallic or polymeric resin system, with either continuous, particulate or chopped fibre reinforcement of a variety of types. In one embodiment, the tiles are stitched through the slots to ensure a continuous fibre reinforcement extends through the thickness of the armour package rather than being present only on its surface.

[0040] Such a continuous fibre reinforcement can also pass through the grooves of the inventive tile. Figures 12a to 12c show a tile suitable for use in this embodiment of the invention. Figure 13 shows two such tiles and fibre reinforcements 9 extending along the grooves 7.

Claims

1. A hard faced armour tile comprising an array of sub-tiles formed by narrow slots.

2. A tile according to claim 1, wherein the sub-tiles are square.

3. A tile according to claim 2, wherein the slots are straight and elongate.

4. A tile according to claim 2, wherein the slots are L-shaped.

5. A tile according to claim 2, wherein the slots are cross-shaped.

6. A tile according to claim 1, wherein the sub-tiles are hexagonal.

7. A tile according to claim 1, wherein the sub-tiles are or of more than one shape.

8. A tile according to any preceding claim, wherein the tile is curved.

9. A tile according to any preceding claim, wherein a chamfer or curved transition zone is formed between an internal surface of each slot and the front surface of the tile.

10. A tile according to claim 9, wherein the slot is asymmetric with the chamfer on one side of the slot at a different angle to the other side.

11. A tile according to claim 9 or 10, wherein the chamfers or zones form a groove around each slot.

12. A tile according to claim 11, wherein the grooves intersect with each other.

13. A tile according to claim 12, wherein the slots and or/ grooves can be formed on a rear surface as well as a front surface of the hard layer.

14. A tile according to any preceding claim, wherein the tile is of ceramic material.

15. A tile according to any one of claims 1 to 13, wherein the tile is of a metal matrix composite material.

16. Armour comprising a plurality of tiles according to any preceding claim in layers and a moulding material holding the tiles together.

17. Armour according to claim 16, wherein the moulding material flows through the slots.

18. Armour according to 16 or 17 when dependent on claim 11,12 or 13, wherein the moulding material flows along the grooves from one slot to another.

19. Armour according to claim 16, 17 or 18, wherein the moulding material is metallic.

20. Armour according to any one of claims 16, 17 or 18, wherein the moulding material comprises a polymeric resin.

21. Armour according to any one of claims 16 to 20, wherein the tiles are stitched together using fibrous material passing through the slots.

22. Armour according to any one of claims 16 to 20, including an absorber layer.

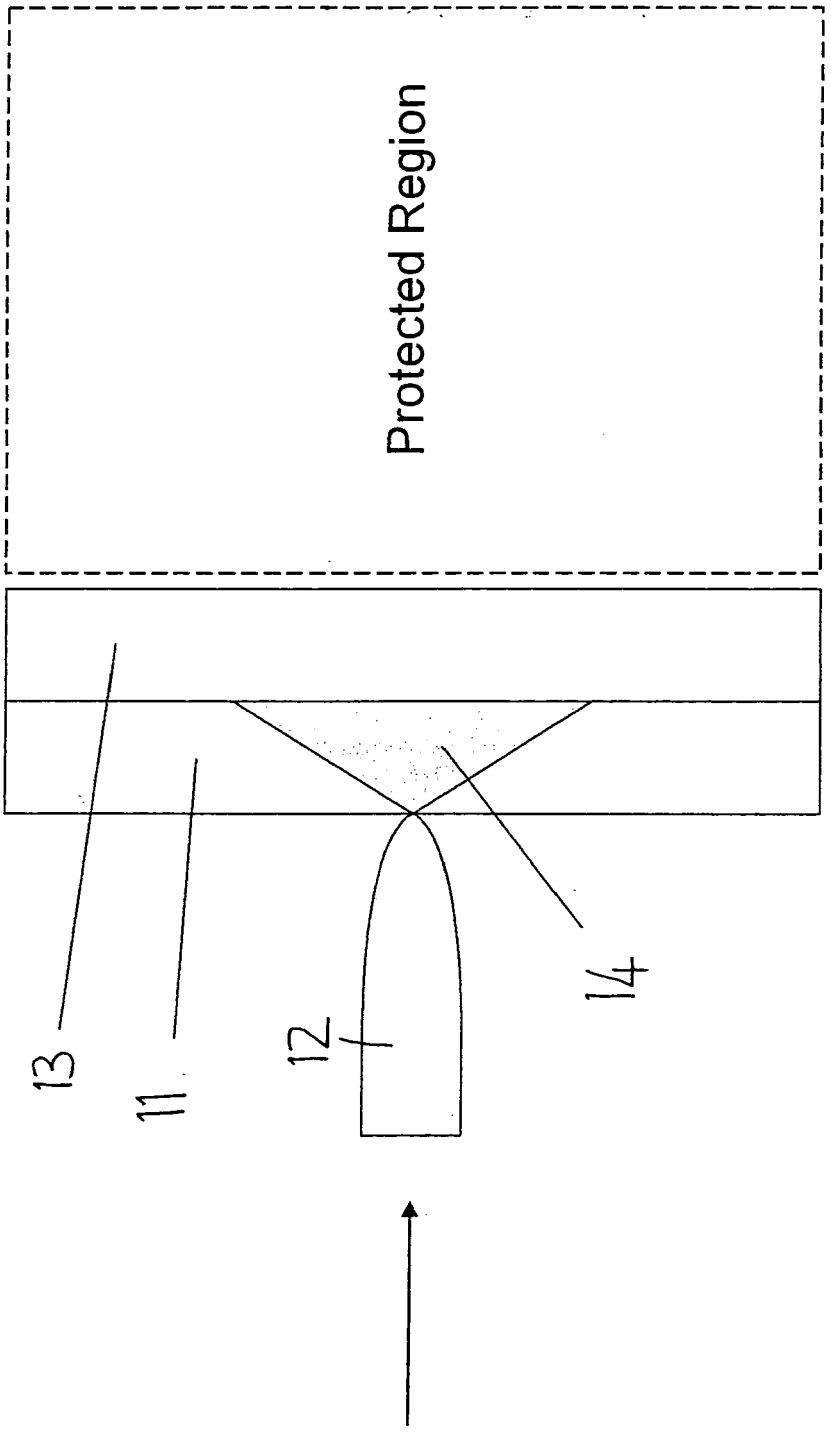

Fig. 1 (Prior Art)

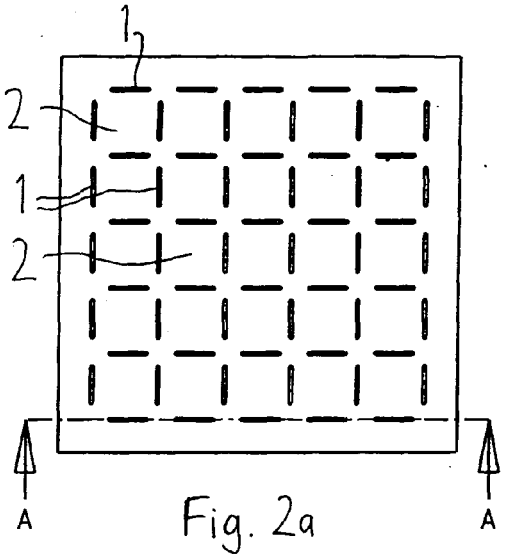

Fig. 2a

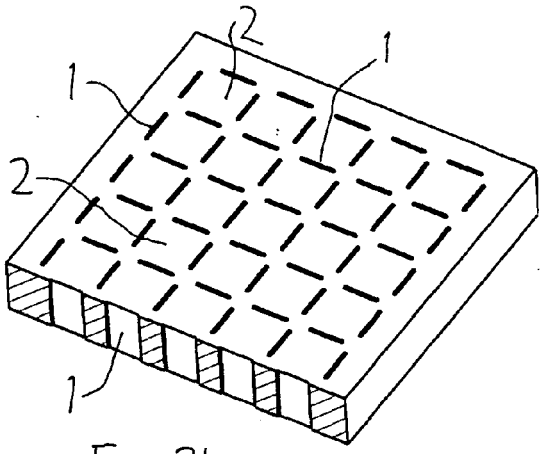

Fig. 2b

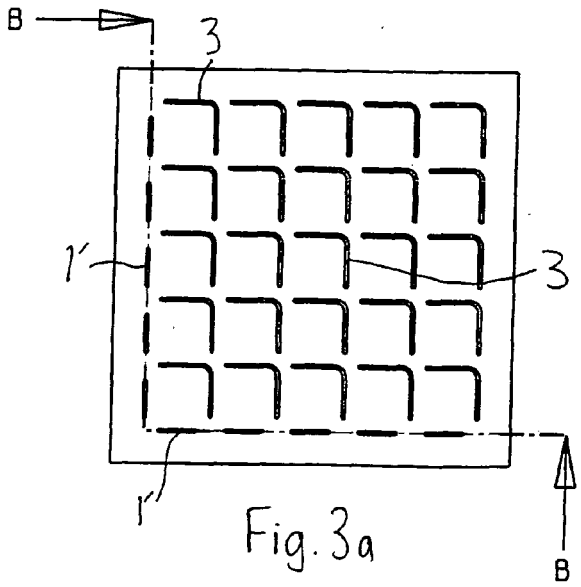

Fig. 3a

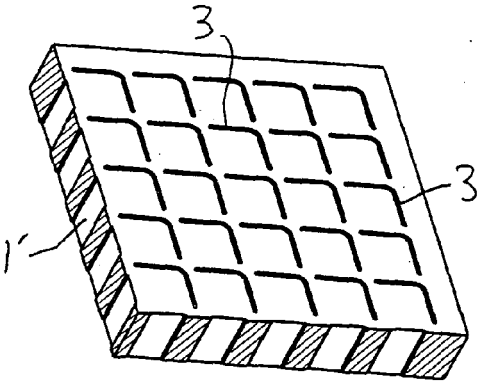

Fig. 3b

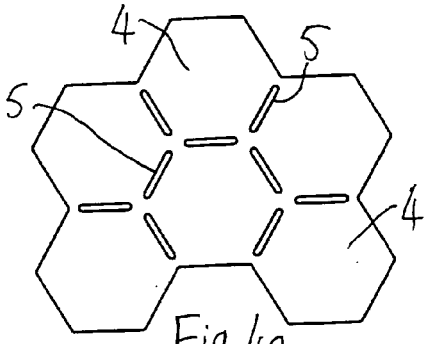

Fig.4a

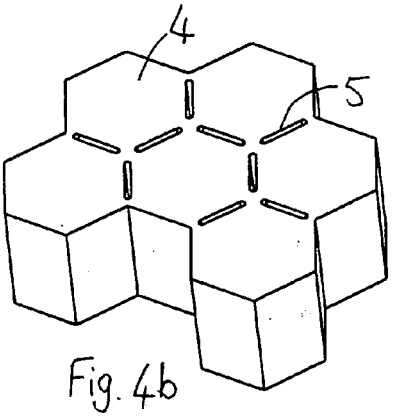

Fig.4b

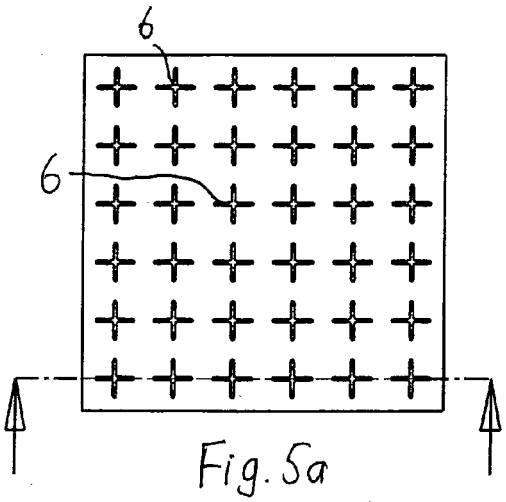

Fig.5a

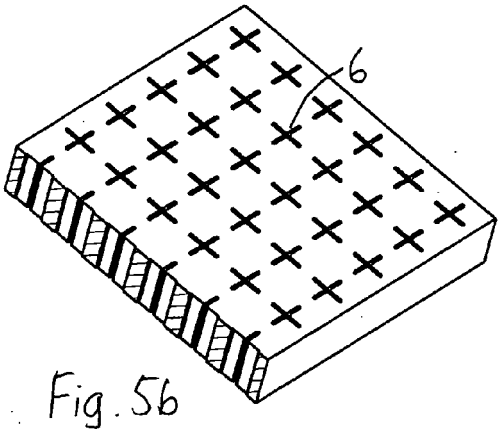

Fig.5b

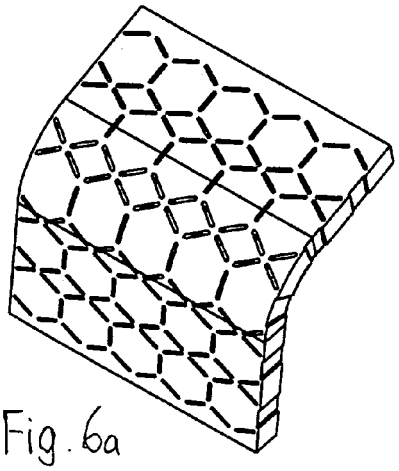

Fig.6a

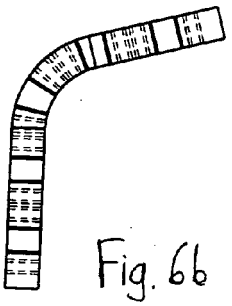

Fig.6b

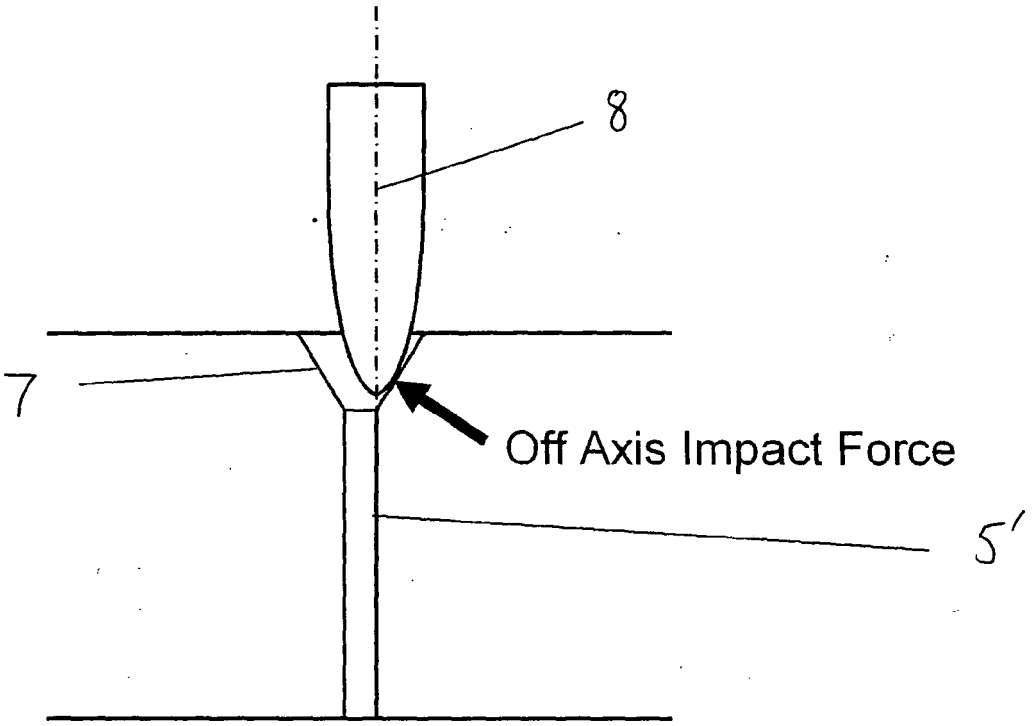

Fig. 7

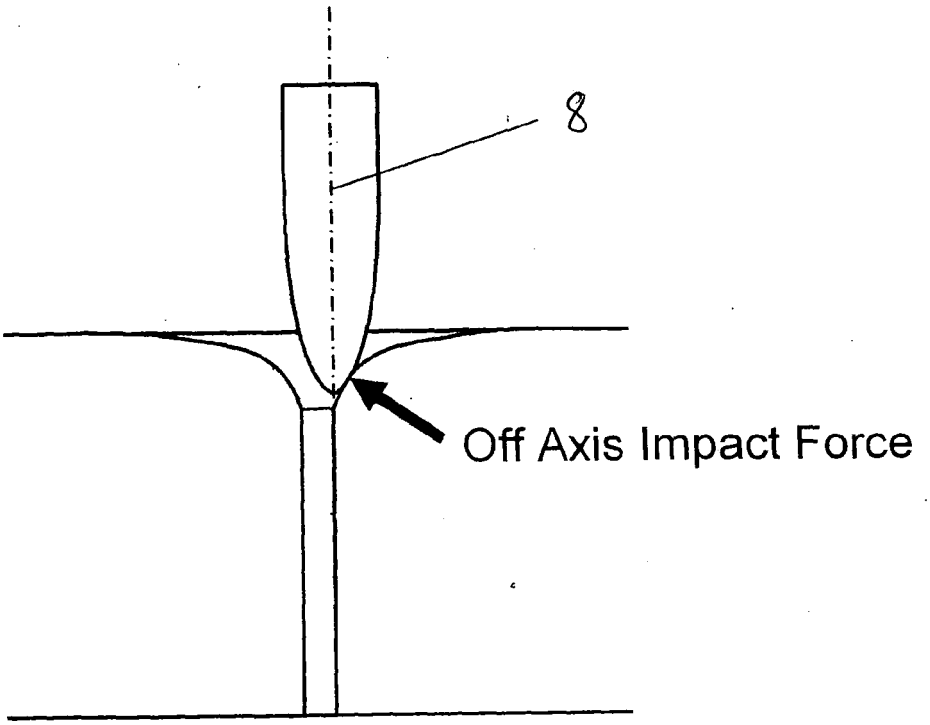

Fig. 8

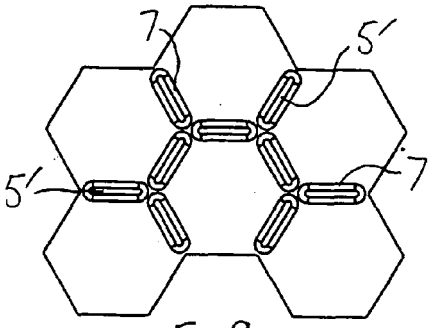

Fig. 9a

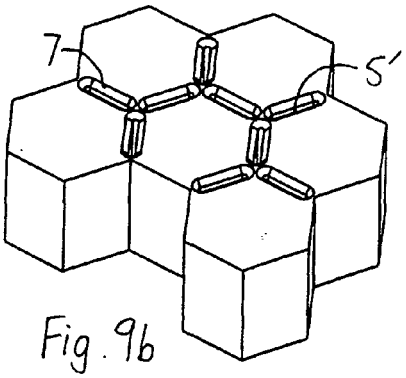

Fig. 9b

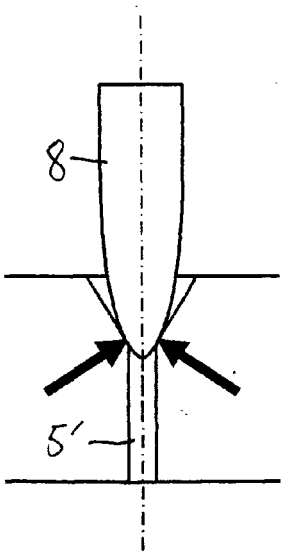

Fig. 10a

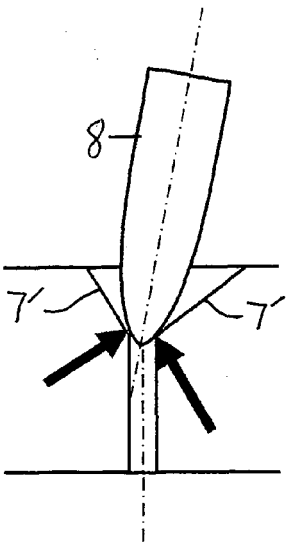

Fig. 10b

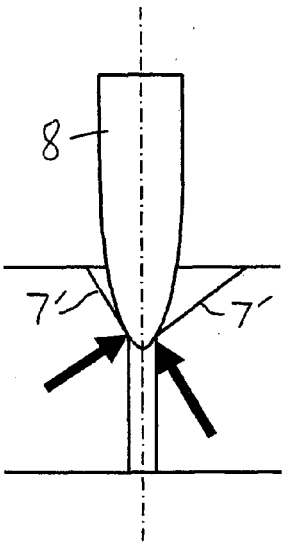

Fig. 10c

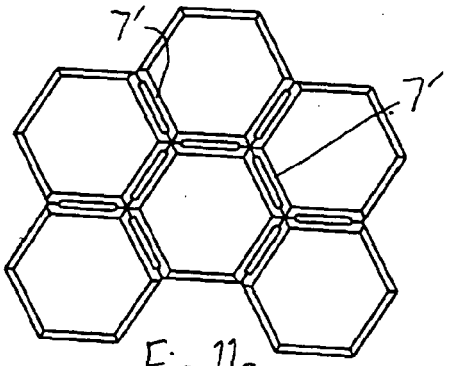

Fig. 11a

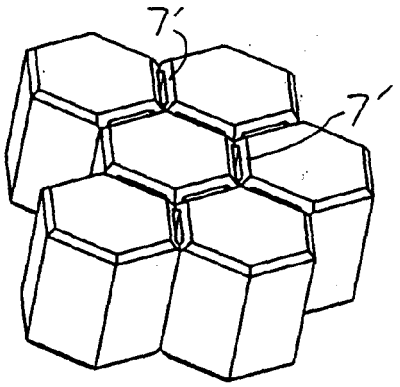

Fig. 11b

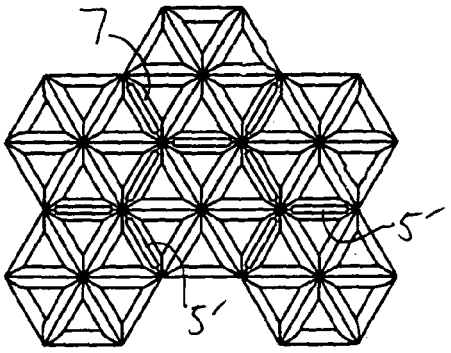

Fig. 12a

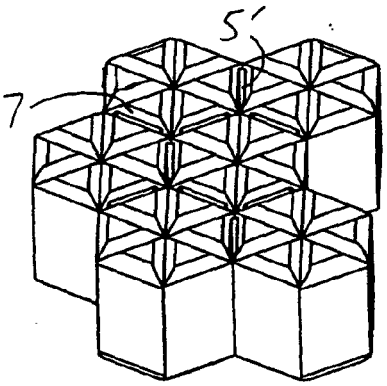

Fig. 12b

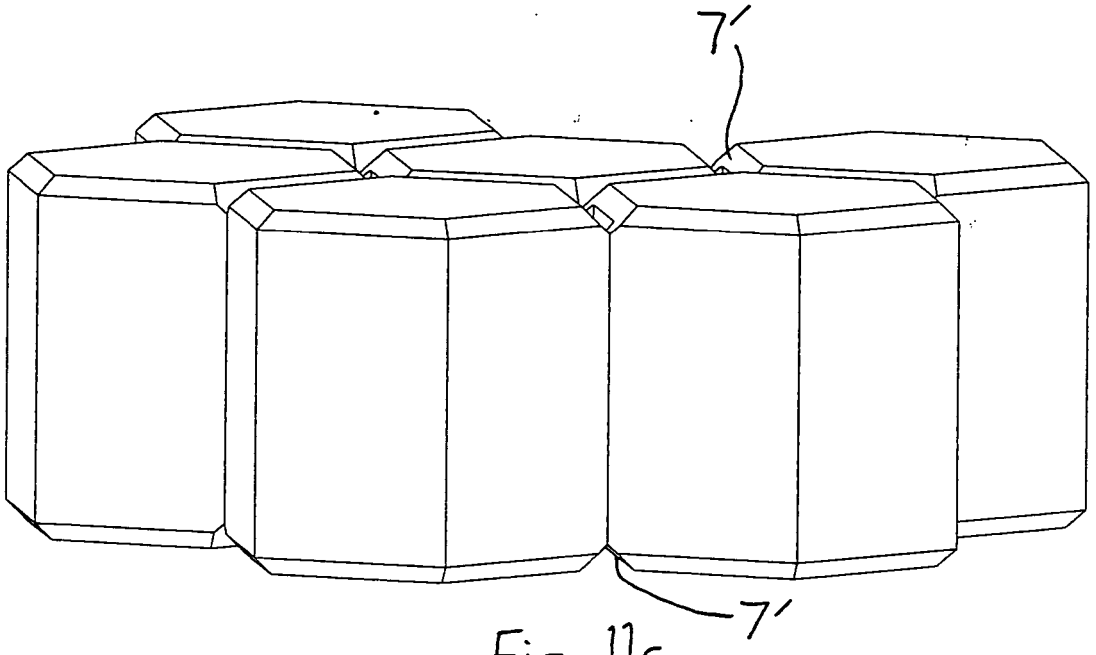

Fig. 11c

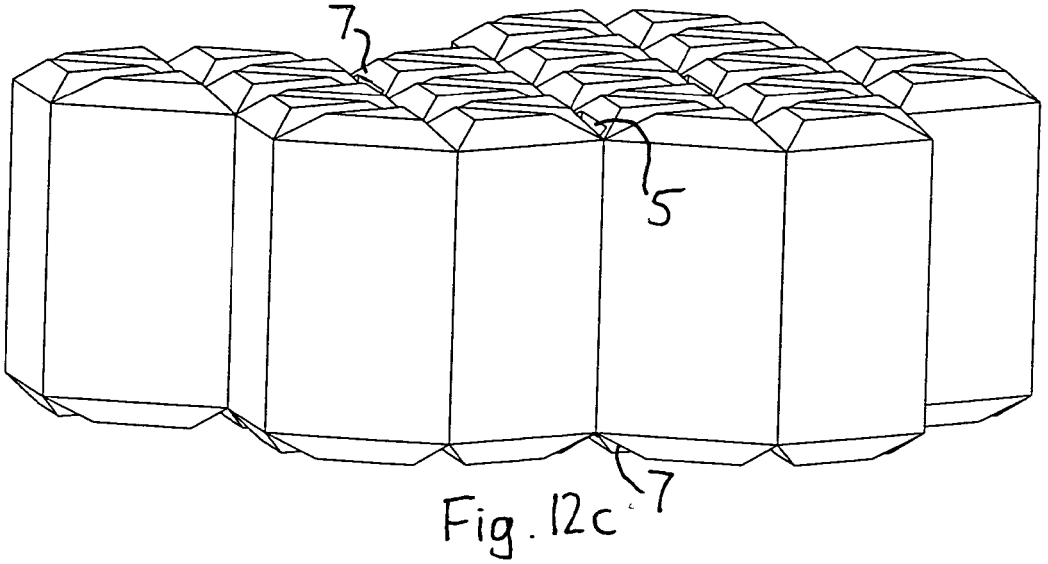

Fig. 12c

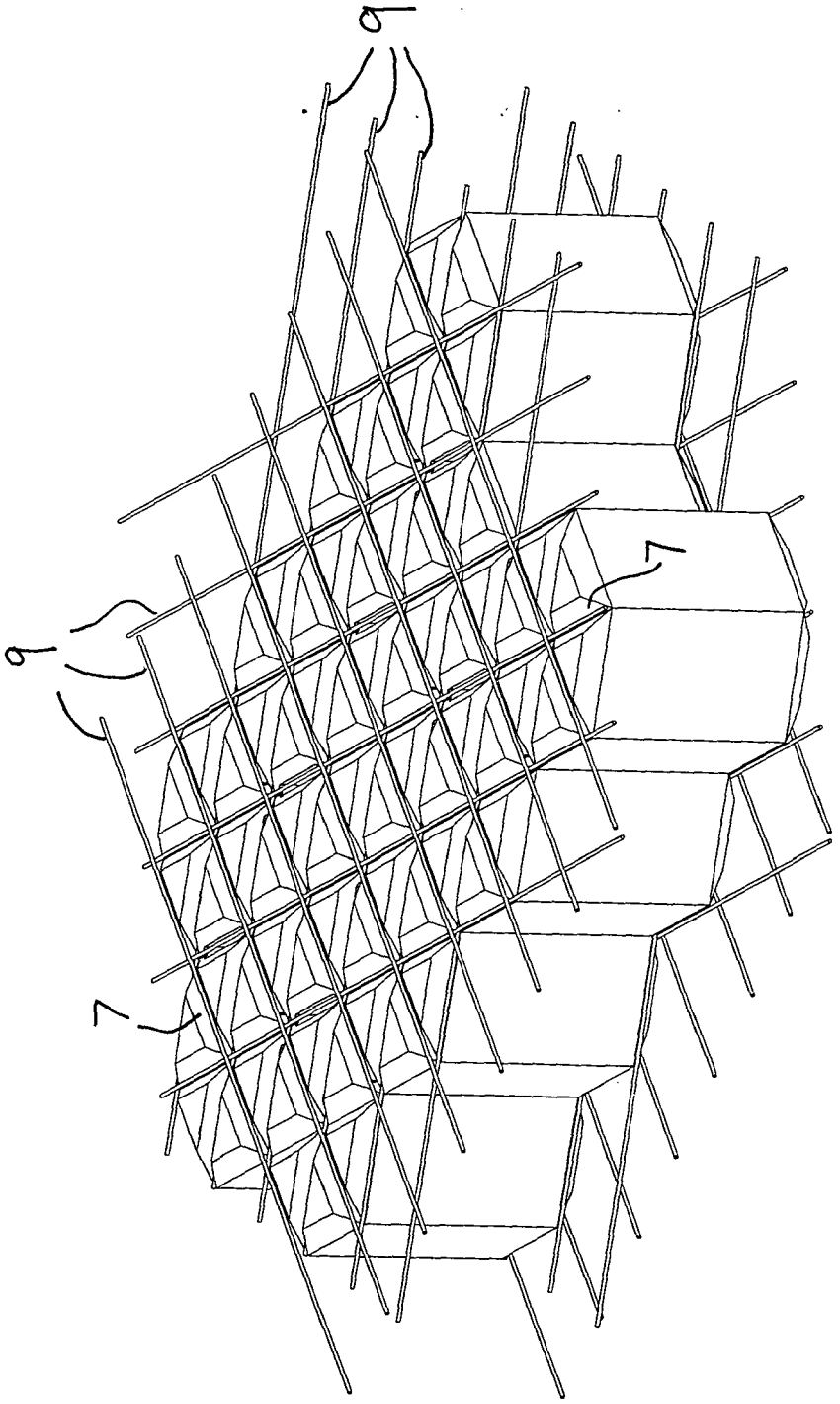

Fig. 13