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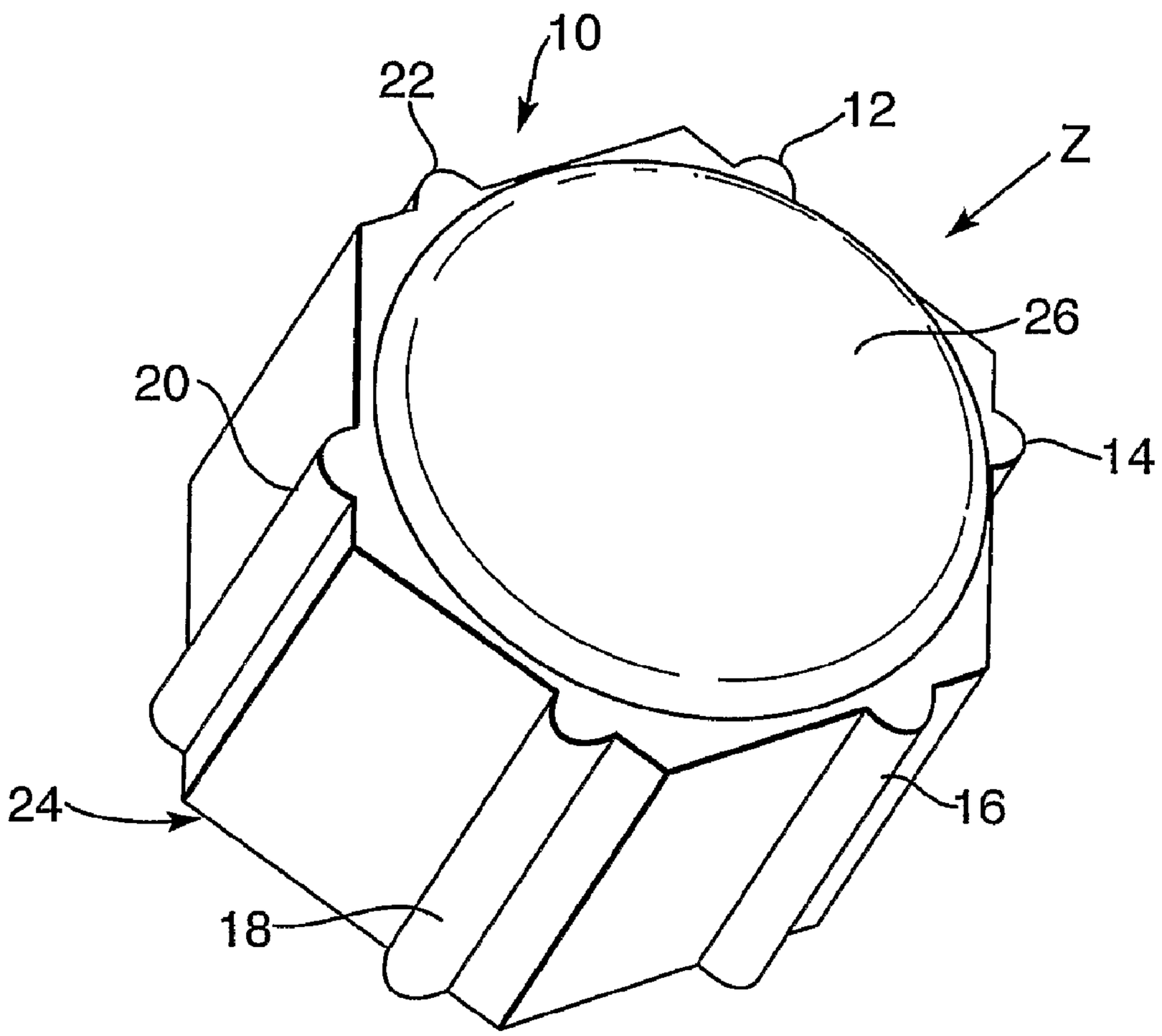
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(54) Title: A CERAMIC ARMOUR ELEMENT FOR USE IN ARMOUR



(57) Abrégé/Abstract:
The invention concerns an armour panel to provide protection from projectiles. The present invention relates to an armour panel comprising a layer of hexagonal ceramic armour elements (10) having a spacing means in the form of lugs (12, 14, 16, 18, 20, 22)

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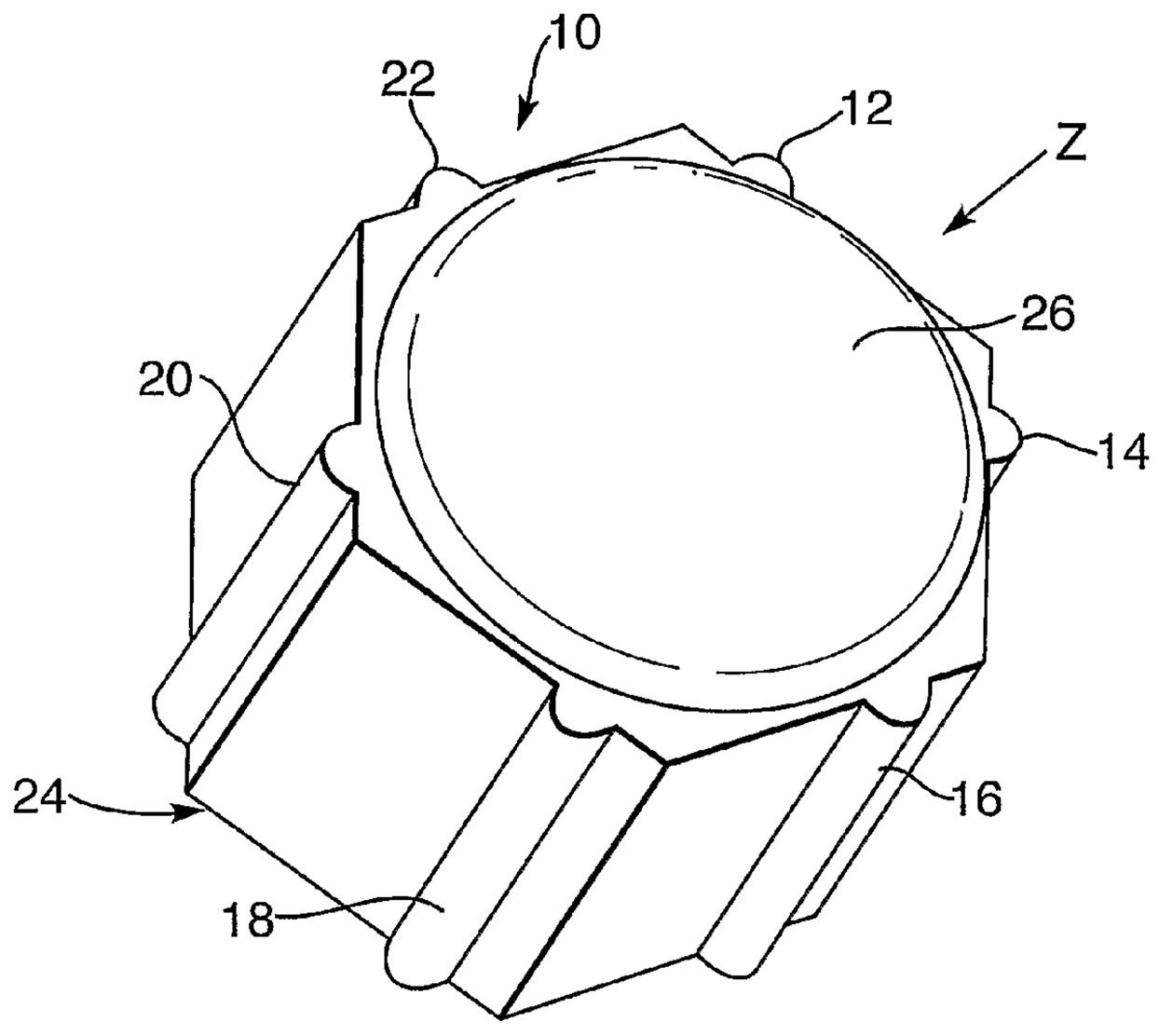
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(54) Title: A CERAMIC ARMOUR ELEMENT FOR USE IN ARMOUR



(57) Abstract: The invention concerns an armour panel to provide protection from projectiles. The present invention relates to an armour panel comprising a layer of hexagonal ceramic armour elements (10) having a spacing means in the form of lugs (12, 14, 16, 18, 20, 22) which are on the side of the ceramic armour element 10 and arranged to co-operate with adjacent ceramic armour elements (100, 200, 300, 400, 500, 600) and form a bond line in the space (48) between elements.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A ceramic armour element for use in armour

The invention concerns an armour panel. More particularly, the invention relates to panels of armour that provide protection from projectiles.

Ceramic armour comprising of panels, which are assembled from individual ceramic elements, are known in the art to provide protection from projectiles. Ceramic armour panels in the prior art are comprised of ceramic elements having a basic element shape assembled in an array. Ceramics are very hard and physically stable, making them highly resistant to melting, bending, stretching, corrosion or wear. Ceramic is known, for example, to be used in armour, insulators and prosthetic joints and may be made from aluminium oxide (alumina), for example. The basic ceramic element shape for armour may be a cylinder, sphere or tile (for example, square or hexagonal shape).

Absorption of momentum and kinetic energy is important in ceramic armour for two reasons. Firstly, to prevent penetration of the armour by a projectile and secondly, to ensure that the momentum and kinetic energy is absorbed in such a manner that the functionality of the armour is not compromised for subsequent impacts. British Patent Application GB 2149482A describes use of a plate or film of synthetic material for absorbing energy in the form of shock waves in a projectile-proof material. The prior art has the disadvantage that material to absorb energy must be added separately to the panel.

In British Patent Application GB2147377A elements are packed together in a mosaic arrangement and bound to a backing plate by an adhesive. An adhesive is distributed

between the embedded elements in European Patent EP0843149B1. In order for adhesive to flow evenly and be distributed evenly in a packed arrangement it is necessary to have spacing between the elements. Elements that are touching enable energy in the form of shock waves to propagate through adjacent elements. That is, energy from a projectile is transferred to an element in the panel and further transferred between touching elements. Where elements are touching energy propagates through the panel as if the panel was one large element.

European Patent EP0843149B1 has the disadvantage that there can be a relatively large vacancy between elements which is not filled with adhesive or ceramic, particularly where spheres are used as the prior art element shape. This vacancy may allow a projectile to penetrate the armour at the space between elements. This disadvantage occurs because of the segment geometry and irregular adhesive distribution within the frame used to assemble the panel. US Patent US3,523,057 attempts to overcome the problem of the vacancy between elements by filling interstitial voids with smaller spherical spheres. This technique has the disadvantage that the panel does not offer a corresponding increase in performance associated with the increase in armour weight due to the addition of small spherical spheres.

Prior art panels, such as those in European Patent EP 0843149B1 are comprised of elements having a shaped lower face, which enables adhesive flow around the under side of the element. Having a shaped lower face on the element has the disadvantage that energy is dissipated over an area of the backing plate larger than the surface area of the transverse cross section of the element. Where the backing plate is made from glass fibre

reinforced plastic (GFRP) the backing plate fails in a progressive manner, with each fibre failing under compression or tension as the profile of the shaped lower face of the element bonded to the adhesive distorts the fibre lattice of the backing plate. The greater the radius of the shaped lower face of the element, the more pronounced the effect over a larger surface of the backing plate.

Large tile designs, such as those in British Patent Application GB214977A have poor capability for multi-hit purposes. Large tiles are usually destroyed when struck by a projectile and energy is transferred to adjacent tiles, potentially causing fractures in these tiles. Energy is also transmitted through the thickness of the tile, and if bonded to a backing plate, can induce de-bonding from the backing plate of the impacted and adjacent tiles. Complete destruction of tiles leaves a large area of the panel having no ceramic layer and thus reduced protection should the panel be struck again in the same vicinity.

The present invention relates to an armour panel comprising a layer of ceramic armour elements and spacing means characterised in that the spacing means comprises a lug on a side of a ceramic armour element arranged to co-operate with an adjacent ceramic armour element. An element is a 3 dimensional object having two faces substantially opposed to each other and having at least three sides joining the faces. Alternatively, the two faces may be circular and joined by one side. A lug is a protrusion from a side of a ceramic element. The spacing means provides substantially uniform spacing for formation of a bond line between sides of adjacent ceramic armour elements in the panel. A bond line is a layer of material between sides of adjacent ceramic armour elements.

In the present invention, the material used for the bond line is an adhesive.

An embodiment of the invention utilises a hexagonal element shape which incorporates a lug on each side of the hexagonal element. When the ceramic armour element is rotated 60^0 through the axis of symmetry of the hexagonal transverse cross section of the ceramic armour element, the position of the lugs on the ceramic armour element is substantially the same. The lugs may be an integral part of the element moulded as part of the element. This element shape with integral lugs has the advantage that assembly of ceramic armour elements in the panel is simplified. When a panel is being assembled, elements are configured to tessellate. The hexagonal symmetry of the elements means that elements can be fitted into the array with minimal effort required for proper orientation to ensure tessellation.

Moulded lugs on the sides of the elements provide space for a controlled uniform bond line between elements, equivalent to the width of the lug. A uniform bond line between elements limits energy transfer to adjacent elements by providing a means for energy absorption. Conventional spherical arrays do not have the uniform bond line achieved by the use of an element with moulded lugs. In the invention, because of the reduction in energy transfer between elements, there is a high probability that ceramic armour elements in the panel remain intact and adjacent ceramic armour elements remain bonded to the backing plate. The panel's inherent shock absorbing properties has the advantage that a plate or film of synthetic material for shock absorbing does not have to be added separately, as in, for example GB 2149482A.

The invention has the further advantage that the lugs separate adjacent elements evenly , thus the requirement of an independent spacing means between each element can be dispensed with. The lugs on the element and the spacing provided between elements facilitates in-plane adhesive infusion and allow for adhesive to be distributed evenly between the elements without any voids. The element shape has the advantage that there is no need for the addition of extra material to fill interstitial voids between elements, as for example the small spheres in US Patent US3,523,057.

Weight is an important consideration in armour because it affects the mobility of the wearer/user. The mass of the panel comprising the hexagonal elements has the same mass as equivalent prior art panels, thus maintaining overall pack weight. Evaluation of a panel according to the invention against an equivalent panel in the prior art shows an improvement in ballistic protection. This has the advantage that an increased level of protection is achieved whilst maintaining the same overall pack weight as a panel in the prior art.

In a preferred embodiment of the invention, the element has a flat lower face. This restricts adhesive flow around the under side of the element. The flat lower face produces an advantage in the mode of failure of the panel. The flat lower face cuts through the glass fibres of the backing plate instead of distorting the fibre lattice in the backing plate. Distortion of the fibre lattice compromises the integrity of the backing plate. Cutting through the backing plate avoids the disadvantages of elements with a shaped lower face, as in European Patent EP 0843149B. Additionally, having lugs on the element provides a preferential plane of movement for the damaged element to move through the array.

The advantage of having a flat lower face on the element, which maintains integrity of the backing plate, combined with the advantage of the inherent shock absorbing properties of the armour panel comprised of hexagonal elements, produces a further advantage in that the multi-hit performance of the armour panel is increased as more of the panel and backing plate remain intact for subsequent impact from projectiles.

With reference to the figures, the invention is described:

Figure 1 is a perspective view of a ceramic armour element of the invention

Figure 2 is a diagram of an array of hexagonal ceramic armour elements

Figure 2a is a diagram of detail of a section of the array showing the co-operation of two elements

Figure 3 is a cut away view of the interior of an armour panel utilising the hexagonal array of Figure 2.

Figure 1 shows a ceramic armour element 10. The ceramic armour element 10 is of hexagonal cross-sectional shape when looking at the element in the direction indicated by Z. The ceramic armour element 10 has lugs 12, 14, 16, 18, 20, 22 on each side of the ceramic armour element. The element has a flat lower face 24 and a convex upper face 26. The convex upper face acts to dissipate energy from initial impact of the projectile over a greater area than if the element had a flat upper face.

Figure 2 shows an array of hexagonal ceramic armour elements including element 10 and identical elements 100, 200, 300, 400, 500, 600. The hexagonal array is arranged such that the lugs 12, 14, 16, 18, 20, 22 on ceramic armour element 10 are co-operating with adjacent ceramic armour elements 100, 200, 300, 400, 500, 600. Lugs 101, 201, 301, 401, 501, 601 on adjacent elements 100, 200, 300, 400, 500, 600 are arranged to be on the opposing half of the sides of the adjacent ceramic armour elements 100, 200, 300, 400, 500, 600 from ceramic armour element 10. There is a continuous space 48 in the entire array of hexagonal elements between the sides of the elements allowing for adhesive flow and ingress and formation of a layer of adhesive between the sides of elements.

Figure 2a shows a detail of a section of the array of hexagonal elements showing the co-operation of two elements. Here the line X through the centre of the sides 11 and 111 defines the left-hand halves and the right-hand halves of the sides 11 and 111. From the perspective of ceramic armour element 10, ceramic armour element 10 has a lug 14 on the right-hand half of the side 11 co-operating with the opposing lugless left-hand half of the adjacent ceramic armour element 100. From the perspective of the ceramic armour element 100 ceramic armour element 100 has a lug 101 on the right-hand half of side 111, co-operating with the opposing lugless left-hand half of adjacent element 10.

A number of ceramic armour elements are assembled to co-operate as in Figure 2a to form an entire panel in a close packed hexagonal arrangement as in Figure 2. A confinement frame 32 is used to keep the individual ceramic armour elements in position while being arranged. In fabrication, when the hexagonal array is completed to form an entire panel in the confinement frame 32, additional adhesive (shown as 62 in Figure 3) is poured over the

panel. The space between the elements 48 facilitates adhesive ingress and results in a bond line between elements. When complete, the panel is partially cured to enable easier handling. The confinement frame 32 is removed after fabrication.

A standard panel as described above contains fixing points to fix the panel to the article to be protected. Panels are assembled to include fixing elements (not shown). Fixing elements are essentially modified steel hexagons having the same dimensions as a ceramic armour element, adapted to facilitate a bolt and adapted to enable lugs of adjacent elements to co-operate with the fixing element. Fixing elements are incorporated into the panel at any position, the position being determined prior to assembly of the panels.

Figure 3 shows a cut away view of the interior of the armour panel of Figure 2. The panel consists of a backing plate 60 with ceramic armour elements 100 and 200 adhered to the backing plate 60 by a layer of adhesive 52. The backing plate material is GFRP (glass fibre reinforced plastic). The adhesive used to bond the ceramic to the backing plate 52 and that has been poured over the ceramic armour elements 62 to form the bond line can be the same or different. An example of suitable adhesive for the purposes of panel assembly would be toughened epoxy or toughened epoxy resin. The properties of the adhesive should be at least one and preferably all of the following:

- To offer a high quality bond to both backing plate and ceramic.
- Have a viscosity sufficient to enable the adhesive to be free flowing, ensuring no voids are present between the ceramic armour elements.
- Cures to a consistency of hard rubber or thermosetting compound.
- Requires only a room temperature cure or a moderate post cure at no greater than 50°C.

When set, the panel (with the confinement frame 32 removed) is encapsulated in an aramid and/or glass reinforced fibre envelope 64.

CLAIMS:

1. An armour panel for protection from projectiles comprising a layer of ceramic armour elements and spacing means characterised in that the spacing means comprises a lug on a side of a ceramic armour element arranged to co-operate with an adjacent ceramic armour element to provide a substantially uniform spacing for a bond line between the sides of the ceramic armour element and the sides of the adjacent ceramic armour elements.

2. An armour panel as claimed in claim 1 characterised in that the ceramic armour element has a lug on each side.

3. An armour panel as claimed in claim 2 characterised in that the lugs on each side of a first ceramic armour element are arranged to be entirely on one half of the sides of the first ceramic armour element, the lugs on adjacent sides of the adjacent ceramic armour elements are arranged to be entirely on the opposing half of the adjacent sides of the adjacent ceramic armour elements.

4. An armour panel as claimed in claim 3 characterised in that the lugs on the first ceramic armour element are not in contact with the lugs on the adjacent ceramic armour elements.

5. An armour panel as claimed in claim 4 characterised in that the ceramic armour elements are moulded and the lugs form an integral part thereof.

6. An armour panel as claimed in claim 5 characterised in that the ceramic armour element has at least one flat face.

7. An armour panel as claimed in claim 6 characterised in that the shape of the ceramic armour element has a hexagonal transverse cross section.

8. An armour panel as claimed in claim 7 characterised in that the ceramic armour element when rotated 60° through the axis of symmetry of the hexagonal transverse cross section of the ceramic armour element the position of the lugs on the ceramic armour element is substantially the same.

9. A ceramic armour element having a spacing means characterised in that the spacing means comprises a lug on a side of a ceramic armour element arranged to be capable of co-operating with a ceramic armour element placed adjacently to it to provide a substantially uniform spacing for a bond line between the sides of the ceramic armour element and the sides of the adjacent ceramic armour elements.

10. A ceramic armour element as claimed in claim 9 characterised in that the ceramic armour element has a lug on each side.

11. A ceramic armour element as claimed in claim 10 characterised in that the ceramic armour element is moulded and the lugs form an integral part thereof.

12. A ceramic armour element as claimed in claim 11 characterised in that the shape of the ceramic armour element has at least one flat face.

13. A ceramic armour element as claimed in claim 12 characterised in that the shape of the ceramic armour element has a hexagonal transverse cross section.

14. A ceramic armour element as claimed in claim 13 characterised in that the ceramic armour element when rotated 60° through the axis of symmetry of the hexagonal transverse cross section of the ceramic armour element the position of the lugs on the ceramic armour element is substantially the same.

Fig.1.

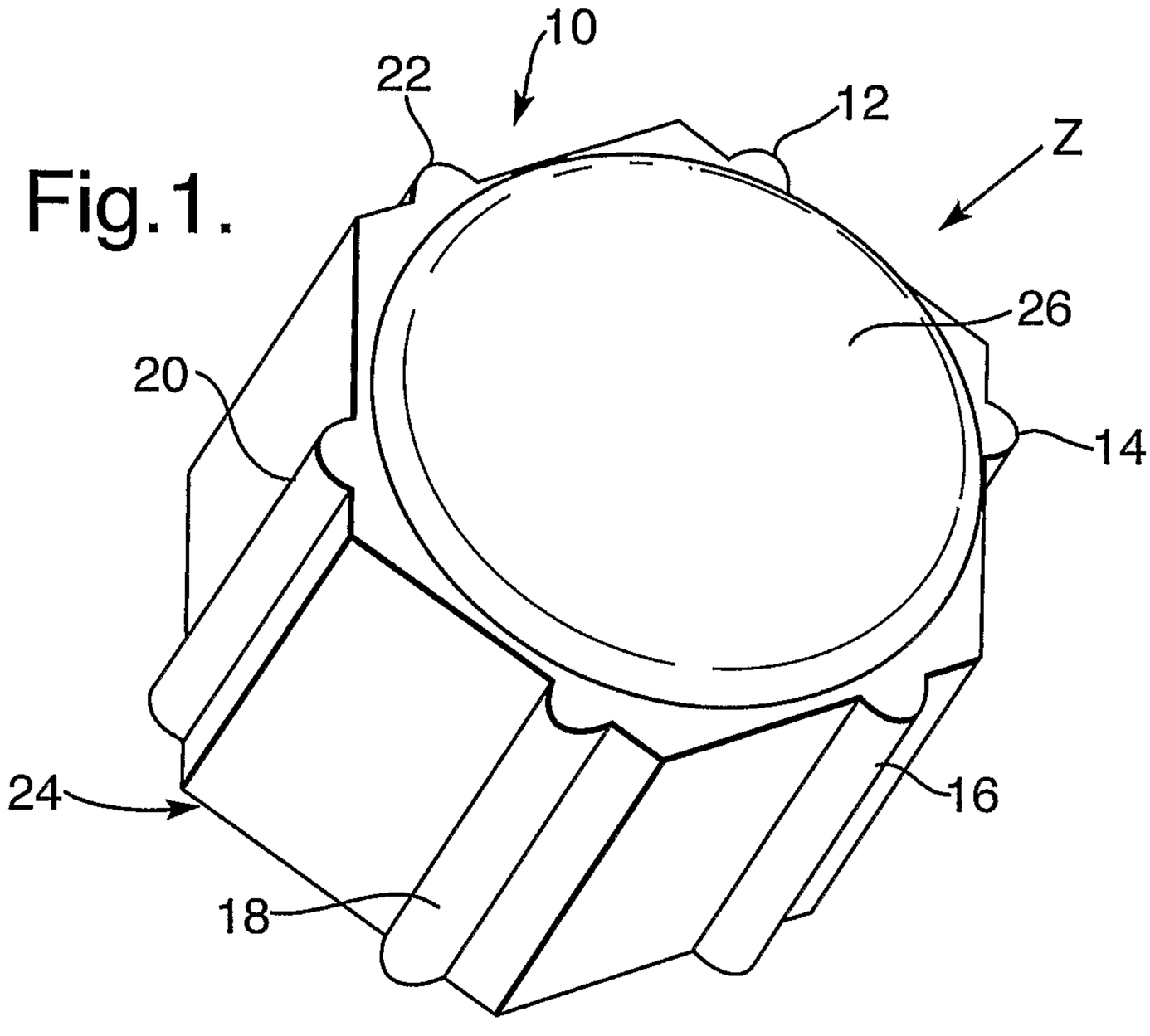


Fig.3.

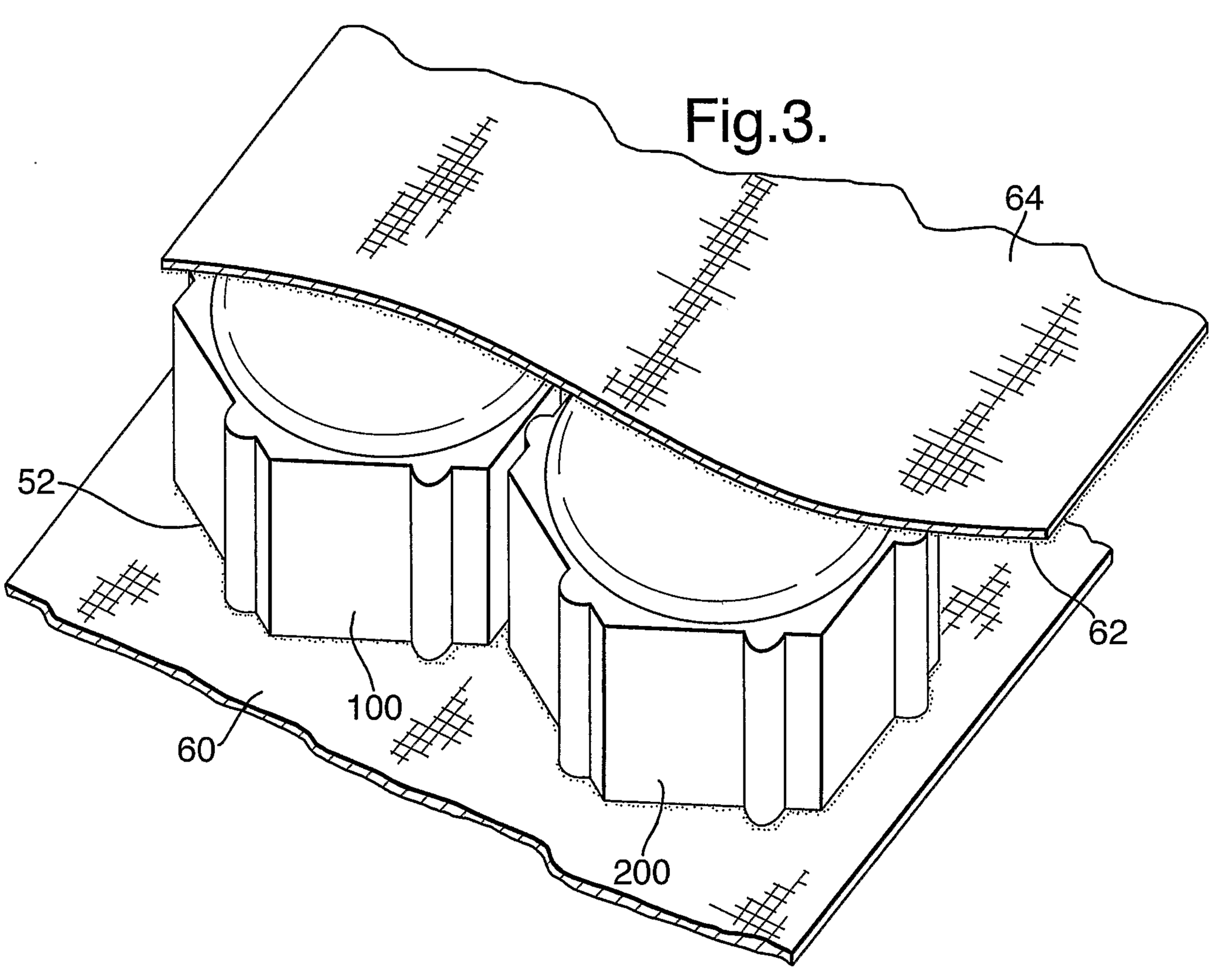


Fig.2.

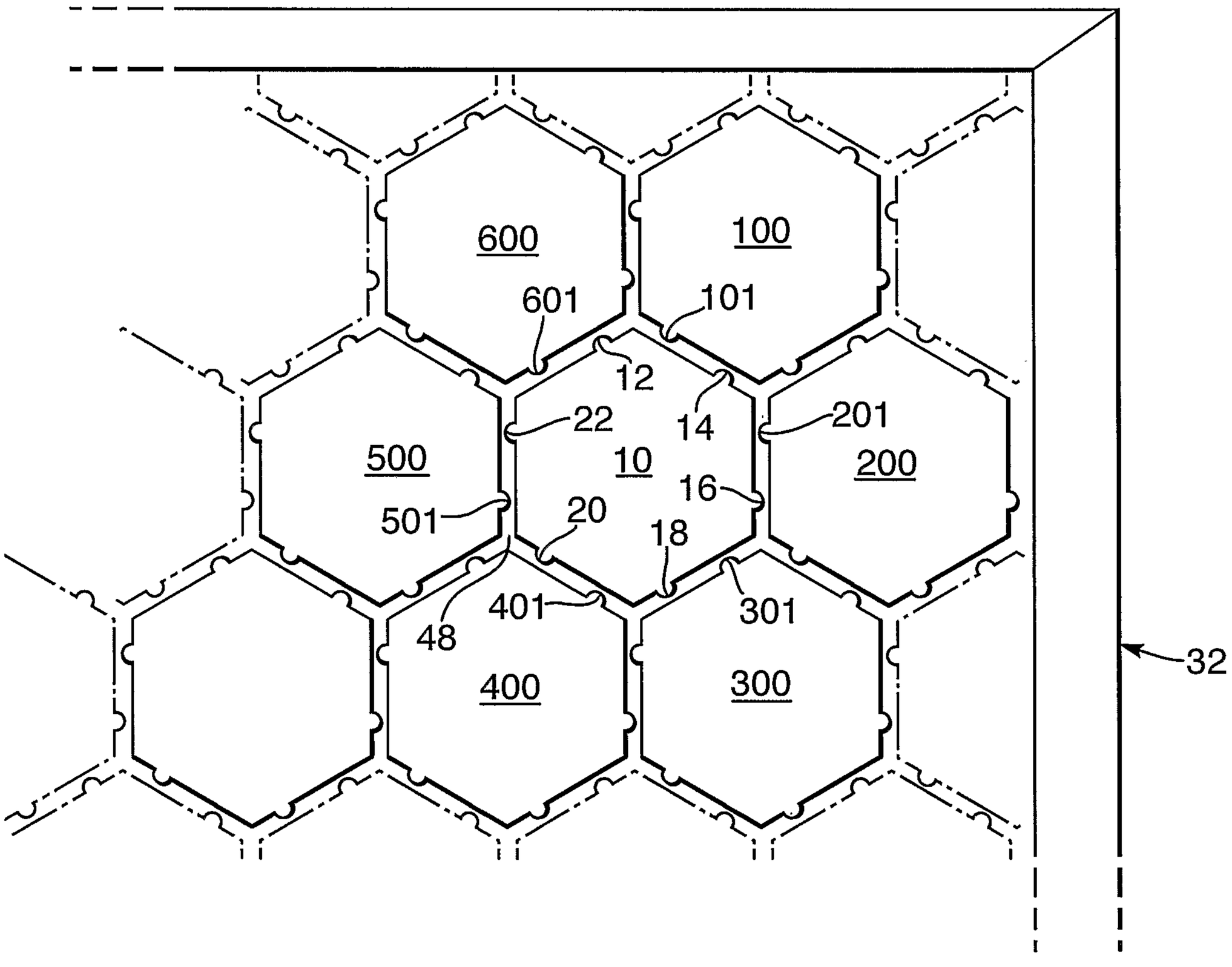
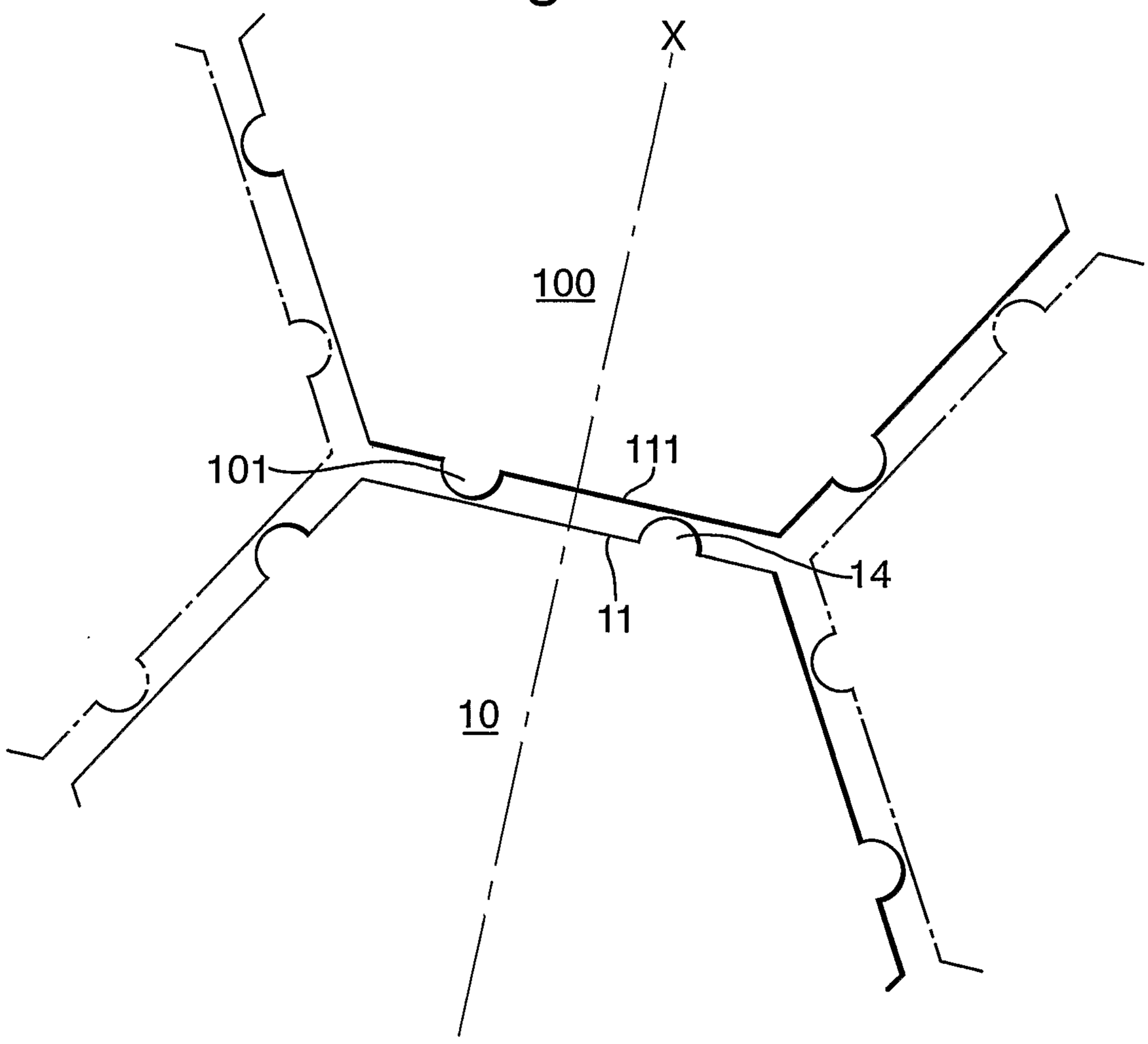
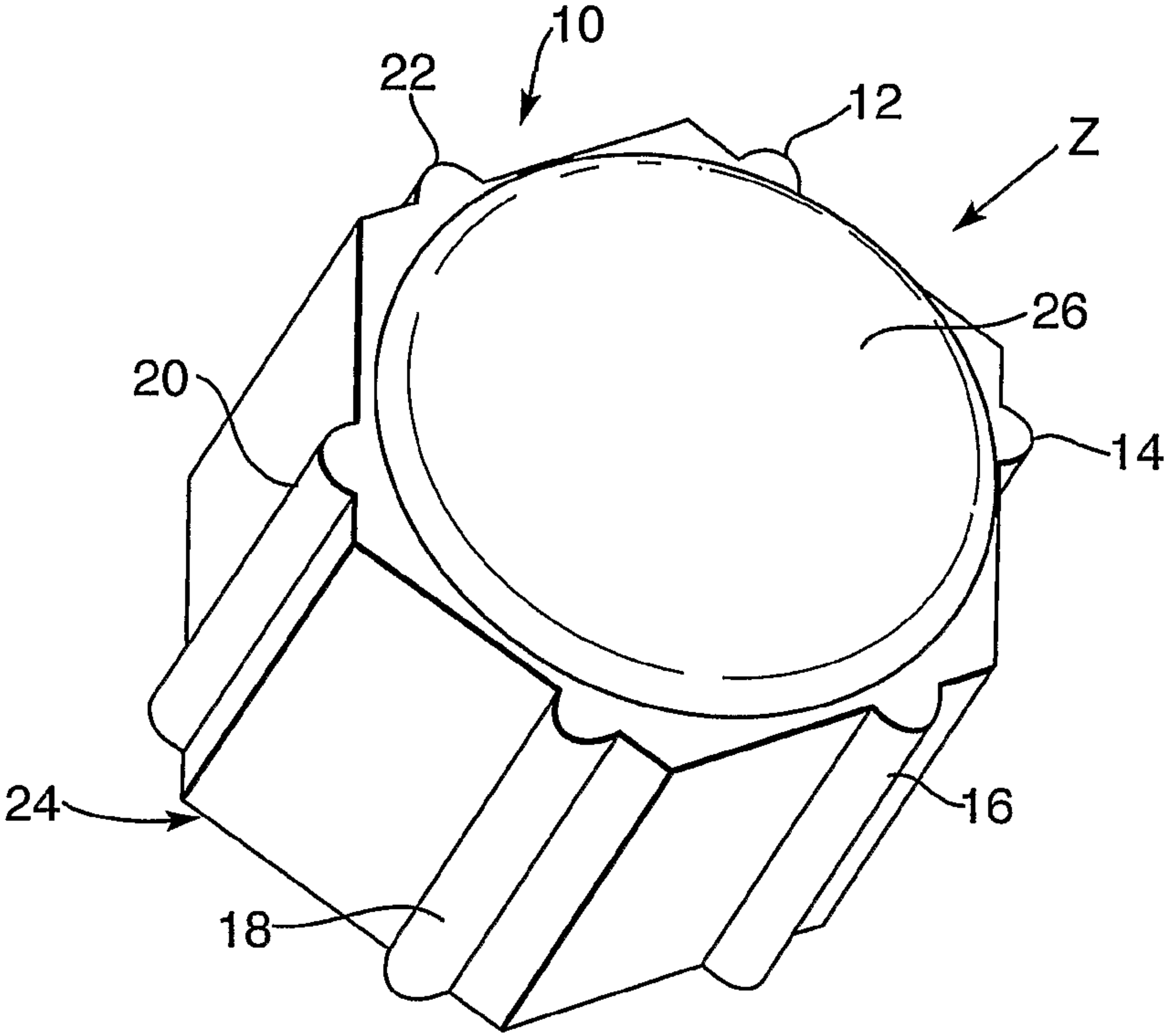

600
100
601
101
12
22
14
201
500
10
200
16
501
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18
401
301
48
400
300
32

Fig.2a.




10
22
12
Z
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18