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(54) **A composite armor plate and ceramic bodies for use therein**

Verbundpanzerplatte und Keramikkörper dafür

Plaque de blindage composite et corps en céramique pour celle-ci

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Description

[0001] The present invention relates to a composite armor panel comprising ceramic bodies, for absorbing and dissipating kinetic energy from projectiles and to ballistic armor panels incorporating the same. More particularly, the invention relates to armored plates, comprising improved ceramic bodies, for providing ballistic protection for light and heavy mobile equipment and for vehicles against high-velocity, armor-piercing projectiles or fragments and especially for use as add-on protection to rigid armorplates such as the steel plates of armored vehicles.

[0002] The present invention is a modification of the inventions described in US Patents 5,763,813; 5,972,819; 6,289,781; 6,112,635; 6,203,908; and 6,408,734 and in WO-A-9815796.

[0003] In US Patent 5,763,813 there is described and claimed a composite armor material for absorbing and dissipating kinetic energy from high velocity, armor-piercing projectiles, comprising a panel consisting essentially of a single internal layer of high density ceramic pellets said pellets having an Al_2O_3 content of at least 93% and a specific gravity of at least 2.5 and retained in panel form by a solidified material which is elastic at a temperature below 250°C ; the majority of said pellets each having a part of a major axis of a length of In the range of about 3-12mm, and being bound by said solidified material in plurality of superposed rows, wherein a majority of each of said pellets is in contact with at least 4 adjacent pellets, the weight of said panel does not exceed 45kg/m².

[0004] In US Patent 6,112,635 there is described and claimed a composite armor plate for absorbing and dissipating kinetic energy from high velocity, armor-piercing projectiles, said plate consisting essentially of a single internal layer of high density ceramic pellets which are directly bound and retained in plate form by a solidified material such that the pellets are bound in a plurality of adjacent rows, wherein the pellets have an Al_2O_3 content of at least 93% and a specific gravity of at least 2.5, the majority of the pellets each have at least one axis of at least 12 mm length said one axis of substantially all of said pellets being in substantial parallel orientation with each other and substantially perpendicular to an adjacent surface of said plate and wherein a majority of each of said pellets is in direct contact with 6 adjacent pellets, and said solidified material and said plate are elastic.

[0005] In WO-A-9815796 corresponding to US Patent 5,972,819, there is described and claimed a ceramic body for deployment in a composite armor panel, said body being substantially cylindrical in shape, with at least one convexly curved end face, wherein the ratio D/R between the diameter D of said cylindrical body and the radius R of curvature of said at least one convexly curved end face is at least 0.64:1.

[0006] In US Patent 6,289,781 there is described and claimed a composite armor plate for absorbing and dissipating kinetic energy from high velocity projectiles, said plate comprising a single internal layer of pellets which

are directly bound and retained in plate form by a solidified material such that the pellets are bound in a plurality of adjacent rows, characterized in that the pellets have a specific gravity of at least 2 and are made of a material selected from the group consisting of glass, sintered refractory material, ceramic material which does not contain aluminum oxide and ceramic material having an aluminum oxide content of not more than 80%, the majority of the pellets each have at least one axis of at least 3 mm length and are bound by said solidified material in said single internal layer of adjacent rows such that each of a majority of said pellets is in direct contact with at least six adjacent pellets in the same layer to provide mutual lateral confinement therebetween, said pellets each have a substantially regular geometric form and said solidified material and said plate are elastic.

[0007] In US Patent 6,408,734 there is described and claimed a composite armor plate for absorbing and dissipating kinetic energy from high velocity, armor-piercing projectiles, as well as from soft-nosed projectiles, said plate comprising a single internal layer of high density ceramic pellets, characterized in that said pellets are arranged in a single layer of adjacent rows and columns, wherein a majority of each of said pellets is in direct contact with at least four adjacent pellets and each of said pellets are substantially cylindrical in shape with at least one convexly-curved end face, further characterized in that spaces formed between said adjacent cylindrical pellets are filled with a material for preventing the flow of soft metal from impacting projectiles through said spaces, said material being in the form of a triangular insert having concave sides complimentary to the convex curvature of the sides of three adjacent cylindrical pellet, or being integrally formed as part of a special interstices-filling pellet, said pellet being in the form of a six sided star with concave sides complimentary to the convex curvature of the sides of six adjacent cylindrical pellets, said pellets and material being bound and retained in plate form by a solidified material, wherein said solidified material and said plate material are elastic.

[0008] As described and explained therein, an incoming projectile may contact the pellet array in one of three ways:

1. Center contact The impact allows the full volume of the pellet to participate in stopping the projectile, which cannot penetrate without pulverizing the whole pellet, an energy-intensive task.
2. Flank contact. The impact causes projectile yaw, thus making projectile arrest easier, as a larger frontal area is contacted, and not only the sharp nose of the projectile. The projectile is deflected sideways and needs to form for itself a large aperture to penetrate, thus allowing the armor to absorb the projectile energy.
3. Valley contact. The projectile is jammed, usually

between the flanks of three pellets, all of which participate in projectile arrest. The high side forces applied to the pellets are resisted by the pellets adjacent thereto as held by the substrate or plate, and penetration is prevented.

[0009] There are four main considerations concerning protective armor panels. The first consideration is weight. Protective armor for heavy but mobile military equipment, such as tanks and large ships, is known. Such armor usually comprises a thick layer of alloy steel, which is intended to provide protection against heavy and explosive projectiles. However, reduction of weight of armor, even in heavy equipment, is an advantage since it reduces the strain on all the components of the vehicle. Furthermore, such armor is quite unsuitable for light vehicles such as automobiles, jeeps, light boats, or aircraft, whose performance is compromised by steel panels having a thickness of more than a few millimeters, since each millimeter of steel adds a weight factor of 7.8 kg/m².

[0010] Armor for light vehicles is expected to prevent penetration of bullets of any type, even when impacting at a speed in the range of 700 to 1000 meters per second. However, due to weight constraints it is difficult to protect light vehicles from high caliber armor-piercing projectiles, e.g. of 12.7 and 14.5 mm and above, since the weight of standard armor to withstand such projectile is such as to impede the mobility and performance of such vehicles.

[0011] A second consideration is cost. Overly complex armor arrangements, particularly those depending entirely on composite materials, can be responsible for a notable proportion of the total vehicle cost, and can make its manufacture non-profitable.

[0012] A third consideration in armor design is compactness. A thick armor panel, including air spaces between its various layers, increases the target profile of the vehicle. In the case of civilian retrofitted armored automobiles which are outfitted with internal armor, there is simply no room for a thick panel in most of the areas requiring protection.

[0013] A fourth consideration relates to ceramic plates used for personal and light vehicle armor, which plates have been found to be vulnerable to damage from mechanical impacts caused by rocks, falls, etc.

[0014] Fairly recent examples of armor systems are described in U.S. Patent No. 4,836,084, disclosing an armor plate composite including a supporting plate consisting of an open honeycomb structure of aluminum; and U.S. Patent No. 4,868,040, disclosing an antiballistic composite armor including a shock-absorbing layer. Also of interest is U.S. Patent 4,529,640, disclosing spaced armor including a hexagonal honeycomb core member.

[0015] Other armor plate panels are disclosed in British Patents 1,081,464; 1,352,418; 2,272,272, and in U.S. Patent 4,061,815 wherein the use of sintered refractory material, as well as the use of ceramic materials, are described.

[0016] In the majority of the patents by the present in-

ventor, the preferred embodiments are pellets having a cylindrical body and at least one convexly curved end face and the especially preferred embodiment is that described in US Patent 5,972,819 wherein the body is substantially cylindrical in shape with at least one convexly curved end face, and preferably two identical convexly curved end faces, wherein the ratio D/R between the diameter D of said cylindrical body and the radius R of curvature of said convexly curved end faces is at least 0.64:1.

[0017] It has now been found that when mounting composite armor panels as add-on protection for the rigid steel armor of light and heavy armored vehicles, the pellet itself is capable of damaging or even penetrating said rigid steel armor backing.

[0018] According to a first aspect of the invention, there is provided a composite armor plate according to claim 1.

[0019] According to a second aspect of the invention, there is provided a composite armor plate according to claim 2.

[0020] In the present invention, the second end face, which is disposed substantially opposite to an outer impact receiving major surface of said plate, is spherical.

[0021] Especially preferred are pellets wherein the second end face is convexly curved and wherein the ratio D/R between the diameter D of the body portion of the pellet and the radius R of the curvature of said convexly curved end second face is between about 0.28:1 and 0.639:1.

[0022] As stated, the composite armor plate and pellets of the present invention are especially preferred whenever used as ballistic protection for a rigid armor plate since it has been found that they increase the area distribution of the initial impact of the pellet as transferred by inertia from the impacting projectile.

[0023] Thus the major difference between the plate and pellets of the present invention and those of the prior plates and pellets in this series is in the shape and size of the end face disposed substantially opposite to the outer impact receiving major surface of the plate (the second end face) however, nevertheless it is still preferred that a majority of said pellets have at least one convexly-curved end face oriented to substantially face in the direction of an outer impact receiving major surface of said plate (i.e. the first end face).

[0024] In the preferred embodiments of the present invention said pellets have at least one axis of at least 9 mm and the present invention is especially applicable and preferred for use with plates incorporating pellets having at least one axis of at least 20 mm.

[0025] In yet further embodiments of the present invention, a channel is provided in a plurality of said pellets to reduce the weight per area thereof.

[0026] In said further embodiments said channel preferably occupies a volume of up to 25% of said pellet

[0027] The cross-sectional shape of the body portions of the pellets may be circular or oval as well as forms that repeat themselves including star shapes, polygonal

cross-sectional shapes and multiple repeating patterns of alternating straight and curved segments.

[0028] The term "elasticity" as used herein relates to the fact that the plates according to the present invention are bent when a load is applied thereto however upon release of said load the plate returns to its original shape without damage.

[0029] For pellets which have a body portion which is not cylindrical, the diameter of the body portion is the length of the longest cross-sectional straight line passing from side to side through the centre of the body portion. When the body portion is cylindrical, the term diameter has its usual meaning.

[0030] The armor plates described in EP-A-0843149 and European Patent Application 98301769.0 are made using ceramic pellets made substantially entirely of aluminum oxide. In WO-A-9815796 the ceramic bodies are of substantially cylindrical shape having at least one convexly-curved end-face, and are preferably made of aluminum oxide.

[0031] In WO 99/60327 it was described that the improved properties of the plates described in the earlier patent applications of this series is as much a function of the configuration of the pellets, which are of regular geometric form with at least one convexly-curved end face (for example, the pellets may be spherical or ovoidal, or of regular geometric cross-section, such as hexagonal, with at least one convexly-curved end face), said panels and their arrangement as a single internal layer of pellets bound by an elastic solidified material, wherein each of a majority of said pellets is in direct contact with at least four adjacent pellets and said curved end face of each pellet is oriented to substantially face in the direction of an outer impact-receiving major surface of the plate. As a result, said specification teaches that composite armor plates superior to those available in the prior art can be manufactured using pellets made of sintered refractory materials or ceramic materials having a specific gravity below that of aluminum oxide, e.g., boron carbide with a specific gravity of 2.45, silicon carbide with a specific gravity of 3.2 and silicon aluminum oxynitride with a specific gravity of about 3.2.

[0032] Thus, it was described in said publication that sintered oxides, nitrides, carbides and borides of magnesium, zirconium, tungsten, molybdenum, titanium and silica can be used and especially preferred for use in said publication and also in the present invention the ceramic bodies utilized herein are formed of a ceramic material selected from the group consisting of sintered oxide, nitrides, carbides and borides of alumina, magnesium, zirconium, tungsten, molybdenum, titanium and silica.

[0033] More particularly, the present invention relates to a ceramic body as defined for absorbing and dissipating kinetic energy from high velocity armor piercing projectiles, wherein said body is made of a material selected from the group consisting of alumina, boron carbide, boron nitride, titanium diboride, silicon carbide, silicon oxide, silicon nitride, magnesium oxide, silicon aluminum

oxynitride and mixtures thereof.

[0034] In preferred embodiments of the present invention said pellets each have a major axis and said pellets are arranged with their major axes substantially parallel to each other and oriented substantially perpendicularly relative to said outer impact-receiving major surface of said panel.

[0035] Thus, in preferred embodiments of the present invention there is provided a composite armor plate as herein defined, wherein a majority of said pellets have at least one convexly-curved end face oriented to substantially face in the direction of an outer impact receiving major surface of said plate.

[0036] The solidified material can be any suitable material, such as aluminum, a thermoplastic polymer such as polycarbonate, or a thermoset plastic such as epoxy or polyurethane.

[0037] When aluminum is used as said solidified material an x-ray of the plate shows the formation of a honeycomb structure around the pellets.

[0038] There are a number of optional but preferred features of the second aspect of the invention, which are independent from one another, as follows. The layer of pellets is preferably the only layer of pellets in the plate.

The pellets are preferably completely embedded or substantially completely embedded in the elastic material. Each of a majority of the pellets is preferably in contact with six adjacent pellets. The plate is preferably elastic.

[0039] In French Patent 2,711,782 there is described a steel panel reinforced with ceramic materials; however said panel does not have the ability to deflect armor-piercing projectiles unless at thickness of about 8-9 mm of steel is used, which adds undesirable excessive weight to the panel and further backing is also necessary thereby further increasing the weight thereof.

[0040] The composite armor plate according to the present invention can be used in conjunction with and as an addition to the standard steel plates provided on armored vehicles or as add on armor for armored vehicles having aluminum or titanium containing rigid surfaces, as well as in conjunction with the laminated armor described and claimed in US Patent 6,497,966.

[0041] According to a further aspect of the invention, there is provided a multi-layered armor panel, comprising an outer, impact-receiving layer formed by a composite armor plate as hereinbefore defined for deforming and shattering an impacting high velocity projectile; and an inner layer adjacent to said outer layer and, comprising a ballistic material for absorbing the remaining kinetic energy from said fragments. Said ballistic material will be chosen according to cost and weight considerations and can be made of any suitable material such as Dyneema, Kevlar, aluminum, steel, titanium, or S2.

[0042] As described, e.g., in U.S. Patent 5,361,678. composite armor plate comprising a mass of spherical ceramic balls distributed in an aluminum alloy matrix is known in the prior art. However, such prior art composite armor plate suffers from one or more serious disadvantages.

tages, making it difficult to manufacture and less than entirely suitable for the purpose of defeating metal projectiles. More particularly, in the armor plate described in said patent, the ceramic balls are coated with a binder material containing ceramic particles, the coating having a thickness of between 0.76 and 1.5 mm and being provided to help protect the ceramic cores from damage due to thermal shock when pouring the molten matrix material during manufacture of the plate. However, the coating serves to separate the harder ceramic cores of the balls from each other, and will act to dampen the moment of energy which is transferred and hence shared between the balls in response to an impact from a bullet or other projectile. Because of this and also because the material of the coating is inherently less hard than that of the ceramic cores, the stopping power of a plate constructed as described in said patent is not as good, weight for weight, as that of a plate in accordance with the present invention.

[0043] U.S. Patent 3,705,558 discloses a lightweight armor plate comprising a layer of ceramic balls. The ceramic balls are in contact with each other and leave small gaps for entry of molten metal. In one embodiment, the ceramic balls are encased in a stainless steel wire screen; and in another embodiment, the composite armor is manufactured by adhering nickel-coated alumina spheres to an aluminium alloy plate by means of a polysulfide adhesive. A composite armor plate as described in this patent is difficult to manufacture because the ceramic spheres may be damaged by thermal shock arising from molten metal contact. The ceramic spheres are also sometimes displayed during casting of molten metal into interstices between the spheres.

[0044] In order to minimize such displacement, US Patents 4,534,266 and 4,945,814 propose a network of interlinked metal shells to encase ceramic inserts during casting of molten metal. After the metal solidifies, the metal shells are incorporated into a composite armor. It has been determined, however, that such network of interlinked metal shells substantially increases the overall weight of the armoured panel and decreases the stopping power thereof.

[0045] It is further to be noted that US Patent 3,705,558 suggests and teaches an array of ceramic balls disposed in contacting pyramidal relationship, which arrangement also substantially increases the overall weight of the armoured panel and decreases the stopping power thereof, due to a billiard-like effect upon impact.

[0046] As will be realized, when preparing the composite armor plate of the present invention, said pellets do not necessarily have to be completely covered on both sides by said solidified material. The pellets are either completely or almost completely covered by said solidified material, wherein outerface surfaces of the plate are formed from the solidified material, the plate having an outer impact receiving face, at which face each pellet is either covered by the solidified material, touches said solidified material which forms surfaces of said outer im-

pact receiving face or, not being completely covered by said solidified material which constitutes surfaces of said outer impact receiving face, bulges therefrom, the solidified material and hence the plate being elastic.

[0047] In USSN 09/924745 there is described and claimed a composite armor plate for absorbing and dissipating kinetic energy from high velocity projectiles, said plate comprising a single internal layer of pellets which are directly bound and retained in plate form by a solidified material such that the pellets are bound in a plurality of adjacent rows, said pellets having a specific gravity of at least 2 and being made of a material selected from the group consisting of glass, sintered refractory material and ceramic material, the majority of the pellets each having at least one axis of at least 3 mm length and being bound by said solidified material in said single internal layer of adjacent rows such that each of a majority of said pellets is in direct contact with six adjacent pellets in the same layer to provide mutual lateral confinement therebetween, said pellets each having a substantially regular geometric form, wherein said solidified material and said plate are elastic, characterized in that a channel is provided in each of a plurality of said pellets, substantially opposite to an outer impact-receiving major surface of said plate, thereby reducing the weight per area of each of said pellets.

[0048] In preferred embodiments described therein each of said channels occupies a volume of up to 25% within its respective pellet.

[0049] Said channels can be bored into preformed pellets or the pellets themselves can be pressed with said channel already incorporated therein.

[0050] Thus, in preferred embodiments of the present invention a channel is provided in the pellets of the armor of the present invention to further reduce the weight per area thereof and preferably said channel occupies a volume of up to 25% of said body.

[0051] In accordance with the present invention said channels are preferably of a shape selected from the group consisting of cylindrical, pyramidal, hemispherical and quadratic, hexagonal prism and combinations thereof.

[0052] As is known, there exists a ballistic effect known in the art in which a projectile striking a cylinder at an angle has a tendency to move this cylinder out of alignment causing a theoretical possibility that a second shot would have more penetration effect on a panel.

[0053] As will be realized, since material is removed from the pellets of the present invention their weight is decreased, as is the overall weight of the entire composite armor plate from which they are formed, thereby providing the unexpected improvement of reduced weight of protective armor panels without loss of stopping power.

[0054] The invention will now be described in connection with certain preferred embodiments with reference to the following illustrative figures so that it may be more fully understood.

[0055] With reference now to the figures in detail, it is

stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

[0056] In the drawings:

FIGURE 1 is an elevational view of a first preferred pellet according to the present invention;

FIG. 2 is an elevational view of a second preferred pellet according to the present invention; and

FIG. 3 is an elevational view of a pellet which is not in accordance with the invention.

[0057] Referring to FIG. 1 there is seen an elevational view of a preferred pellet 2 according to the present invention having a substantially cylindrical body 4 and two convexly curved end faces 6 and B. As indicated in the drawing, end face 6 which is designed to serve as the outer impact receiving end face of the pellet 2 has a radius of curvature of 17 mm as indicated by the letter R and the cylinder has a diameter of 28 mm. In contradistinction the end face 8 designed to be disposed substantially opposite to the outer impact receiving end face 6 has a spherical surface with a radius of curvature of 100 mm. Thus as will be realized, in this embodiment, the ratio D/R between the diameter of the body of the pellet and the radius R of the curvature of said convexly curved end face B is 0.28:1.

[0058] Referring to FIG. 2 there is seen an elevational view of a further preferred pellet 20 according to the present invention having a substantially cylindrical body 24 and two convexly curved end faces 26 and 28. As indicated in the drawing, end face 26 which is designed to serve as the outer impact receiving end face of the pellet 20 has a radius of curvature of 17 mm as indicated by the letter R and the cylinder has a diameter of 28 mm. In contradistinction the end face 28 designed to be disposed substantially opposite to the outer impact receiving end face 26 has a spherical surface with a radius of curvature of 44 mm. Thus as will be realized, in this embodiment, the ratio D/R between the diameter of the body of the pellet and the radius R of the curvature of said convexly curved end face 28 is 0,636:1.

[0059] Referring now to FIG. 3 there is seen a pellet to which is not in accordance with the invention. Thus as seen, said pellet, 30' is formed of a cylindrical body 34 with one convexly curved end face 36 and a further end face 38 disposed substantially opposite to the outer impact receiving end face 36 wherein said end face 38 is in the form of an outwardly tapered truncated cone. As

with the embodiments discussed with reference to FIGURES 1 and 2, end face 36 which is designed to serve as the outer impact receiving end face of the pellet 30' has a radius of curvature of 17 mm as indicated by the letter R and the cylinder has a diameter of 28 mm. In contradistinction the end face 38 designed to be disposed substantially opposite to the outer impact receiving end face 36 is in the form of a chamfer with a height of 2 mm and wherein the angle of the outwardly tapered truncated cone vis a vis the cylindrical body is 45°. In addition said pellet 30' is provided with a channel 40 substantially opposite to the outer impact-receiving end face 36 of said pellet, thereby reducing the weight per area of said pellet. In the embodiment shown, said channel has a diameter of 15 mm.

[0060] The pellets 2, 20 and 30' are all formed of a ceramic material. Preferred ceramics are sintered oxide, nitrides, carbides and borides of alumina, magnesium, zirconium, tungsten, molybdenum, titanium and silica.

[0061] Preferred materials are typically alumina, boron carbide, boron nitride, titanium diboride, silicon carbide, silicon oxide, silicon nitride, magnesium oxide, silicon aluminum oxynitride and mixtures thereof.

[0062] While not shown, the plates of the present invention or at least the outer surface thereof can be further covered by a thin layer of kevlar, fiberglass, or even aluminum for protection and for concealing the structure thereof.

[0063] It will be evident to those skilled in the art that the invention is not limited to the details of the foregoing illustrative embodiments and that the present invention may be embodied in other specific forms. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims.

Claims

1. A composite armor plate for absorbing and dissipating kinetic energy from high-velocity projectiles, the plate comprising a single layer of pellets (2, 20, 30, 30'), wherein each pellet is made of a ceramic material and has a body portion (4, 24, 34) with a substantially geometrical cross-sectional area, the geometrical cross-sectional area having an axis of symmetry, said each pellet having first and second end faces (6, 8, 26, 28, 36, 38) projecting, respectively, from opposite ends of the body portion (4, 24, 34) and each end face (6, 8, 26, 28, 36, 38) having an outwardly decreasing cross-sectional area, the second end face (8, 28, 38) being spherical and having a height which is less than 15% of the diameter of the body portion, the first end face (6, 26, 36) having a height which is greater than the height of the second end face, the pellets being bound and retained in plate form by a solidified elastic material, substantially internally within the solidified elastic material,

such that the pellets (2, 20, 30, 30') are bound in a plurality of spaced-apart rows and columns, the pellets (2, 20, 30, 30') being substantially fully embedded in the solidified elastic material, wherein the solidified elastic material and the plate are elastic, wherein a majority of each of the pellets (2, 20, 30, 30') is in direct contact with six adjacent pellets in the same layer to provide mutual lateral confinement therebetween, wherein the second end face (8, 28, 38) of each pellet is disposed substantially opposite to an outer impact receiving major surface of the plate and the first end face (6, 26, 36) of each pellet is an impact receiving end face.

2. A composite armor plate comprising a plurality of pellets (2, 20, 30, 30') arranged in a layer and embedded in a solidified elastic material, wherein each pellet is made of a ceramic material and has a body portion (4, 24, 34) with a substantially geometrical cross-sectional area, the geometrical cross-sectional area having an axis of symmetry, said each pellet having first and second end faces (6, 8, 26, 28, 36, 38) projecting, respectively, from opposite ends of the body portion (4, 24, 34) and each end face (6, 8, 26, 28, 36, 38) having an outwardly decreasing cross-sectional area, the second end face (8, 28, 38) being spherical and having a height which is less than 15% of the diameter of the body portion, the first end face (6, 26, 36) having a height which is greater than the height of the second end face, each pellet body portion having an axis and a constant geometric cross-section normal to the axis, wherein the constant geometric cross-section has an axis of symmetry, each pellet (2, 20, 30, 30') contacting adjacent pellets at respective body portions (4, 24, 34) and the second end faces (8, 28, 38) being disposed substantially opposite to an outer impact receiving major surface of the plate, wherein the height of each second end face is the height of the second end face along the corresponding body portion axis, and wherein each first end face (6, 26, 36) is an impact receiving end face.
3. A composite armor plate according to claim 1 or claim 2, wherein for each second end face (8, 28), the ratio D/R between the diameter D of the body portion (8, 24) of the pellet (2, 20) and the radius R of the curvature of the second end face (8, 28) is between 0.28:1 and 0.639:1.
4. A composite armor plate according to any preceding claim, wherein a majority of the first end faces (6, 6, 36) are convexly-curved and oriented to substantially face in the direction of the outer impact receiving major surface of the plate.
5. A composite armor plate according to any preceding claim, wherein the pellets (2, 20, 30, 30') have at

least one axis of at least 9mm.

6. A composite armor plate according to claim 5, wherein the pellets (2, 20, 30, 30') have at least one axis of at least 20mm.
7. A composite armor plate according to any preceding claim, wherein each of said pellets (2, 20, 30, 30') is formed of a ceramic material selected from the group consisting of sintered oxide, nitrides, carbides and borides of alumina, magnesium, zirconium, tungsten, molybdenum, titanium and silica.
8. A composite armor plate according to any preceding claim, wherein each of said pellets (2, 20, 30, 30') is formed of a material selected from the group consisting of alumina, boron carbide, boron nitride, titanium diboride, silicon carbide, silicon oxide, silicon nitride, magnesium oxide, silicon aluminium oxynitride and mixtures thereof.
9. A composite armor plate according to claim 2 or any claim dependent thereon, wherein said solidified elastic material and said plate are elastic.
10. A composite armor plate according to any preceding claim **characterised in that** a channel (40) is provided in a plurality of said pellets (30') to reduce the weight per area thereof.
11. A composite armor plate according to claim 10, wherein said channel (40) occupies a volume of up to 25% of said pellet (30').
12. A multi-layered armor panel, comprising an outer, impact-receiving layer formed by a composite armor plate according to any preceding claim for deforming and shattering an impacting high velocity projectile, and an inner layer adjacent to the outer layer and comprising a ballistic material for absorbing the remaining kinetic energy from said fragments.
13. A multi-layered armor panel according to claim 12, wherein the ballistic material is Dyneema (TM), Kevlar (TM), aluminium, steel, titanium or S2.
14. Use of a composite armor plate according to any one of claims 1 to 11, as ballistic protection for a rigid armor plate.

Patentansprüche

1. Verbundpanzerungsplatte zum Absorbieren und Ableiten kinetischer Energie von Hochgeschwindigkeitsgeschossen, wobei die Platte eine einzelne Lage Pellets (2, 20, 30, 30') umfasst, wobei jedes Pellet aus einem Keramikmaterial hergestellt ist und einen

- Körperabschnitt (4, 24, 34) mit einem im Wesentlichen geometrischen Querschnitt aufweist, wobei der geometrische Querschnitt eine Symmetrieachse aufweist, wobei jedes Pellet eine erste und eine zweite Endfläche (6, 8, 26, 28, 36, 38) aufweist, die jeweils von gegenüberliegenden Enden des Körperabschnitts (4, 24, 34) vorspringen, und jede Endfläche (6, 8, 26, 28, 36, 38) einen nach außen hin zunehmenden Querschnitt aufweist, wobei die zweite Endfläche (8, 28, 38) kugelförmig ist und eine Höhe aufweist, die weniger als 15 % des Durchmessers des Körperabschnitts beträgt, wobei die erste Endfläche (6, 26, 36) eine Höhe aufweist, die größer als die Höhe der zweiten Endfläche ist, wobei die Pellets durch ein verfestigtes elastisches Material in der Plattenform gebunden und gehalten werden, im Wesentlichen innerhalb des verfestigten elastischen Materials, derart, dass die Pellets (2, 20, 30, 30') in einer Vielzahl von beabstandeten Reihen und Spalten gebunden sind, wobei die Pellets (2, 20, 30, 30') im Wesentlichen vollständig in dem verfestigten elastischen Material eingebettet sind, wobei das verfestigte elastische Material und die Platte elastisch sind, wobei ein Großteil eines jeden der Pellets (2, 20, 30, 30') in direktem Kontakt mit sechs benachbarten Pellets in derselben Lage steht, um einen gegenseitigen seitlichen Einschluss dazwischen bereitzustellen, wobei die zweite Endfläche (8, 28, 38) jedes Pellets im Wesentlichen gegenüber einer äußeren Aufprall aufnehmenden Hauptfläche der Platte angeordnet ist und die erste Endfläche (6, 26, 36) eines jeden Pellets eine Aufprall aufnehmende Endfläche ist.
2. Verbundpanzerungsplatte, umfassend eine Vielzahl von Pellets (2, 20, 30, 30'), die in einer Lage angeordnet und in einem verfestigten elastischen Material eingebettet sind, wobei jedes Pellet aus einem Keramikmaterial hergestellt ist und einen Körperabschnitt (4, 24, 34) mit einem im Wesentlichen geometrischen Querschnitt aufweist, wobei der geometrische Querschnitt eine Symmetrieachse aufweist, wobei jedes Pellet eine erste und eine zweite Endfläche (6, 8, 26, 28, 36, 38) aufweist, die jeweils von gegenüberliegenden Enden des Körperabschnitts (4, 24, 34) vorspringen, und jede Endfläche (6, 8, 26, 28, 36, 38) einen nach außen hin abnehmenden Querschnitt aufweist, wobei die zweite Endfläche (8, 28, 38) kugelförmig ist und eine Höhe aufweist, die kleiner als 15% des Durchmessers des Körperabschnitts ist, wobei die erste Endfläche (6, 26, 36) eine Höhe aufweist, die größer als die Höhe der zweiten Endfläche ist, wobei jeder Pelletkörperabschnitt eine Achse und einen konstanten geometrischen Querschnitt senkrecht zu der Achse aufweist, wobei der konstante geometrische Querschnitt eine Symmetrieachse aufweist, wobei jedes Pellet (2, 20, 30, 30') mit benachbarten Pellets an jeweiligen Körperabschnitten (4, 24, 34) in Kontakt steht und die zweiten Endflächen (8, 28, 38) im Wesentlichen gegenüber einer äußeren Aufprall aufnehmenden Hauptfläche der Platte angeordnet sind, wobei die Höhe jeder zweiten Endfläche die Höhe der zweiten Endfläche entlang der entsprechenden Körperabschnittsachse ist, und wobei jede erste Endfläche (6, 26, 36) eine Aufprall aufnehmende Endfläche ist.
 3. Verbundpanzerungsplatte nach Anspruch 1 oder Anspruch 2, wobei für jede zweite Endfläche (8, 28) das Verhältnis D/R zwischen dem Durchmesser D des Körperabschnitts (8, 24) des Pellets (2, 20) und der Radius R der Krümmung der zweiten Endfläche (8, 28) zwischen 0,28:1 und 0,639:1 beträgt.
 4. Verbundpanzerungsplatte nach einem der vorangehenden Ansprüche, wobei ein Großteil der ersten Endflächen (6, 6, 36) konvex gekrümmt ist und derart ausgerichtet ist, dass er in die Richtung der äußeren Aufprall aufnehmenden Hauptfläche der Platte gewandt ist.
 5. Verbundpanzerungsplatte nach einem der vorangehenden Ansprüche, wobei die Pellets (2, 20, 30, 30') wenigstens eine Achse von wenigstens 9 mm aufweisen.
 6. Verbundpanzerungsplatte nach Anspruch 5, wobei die Pellets (2, 20, 30, 30') wenigstens eine Achse von wenigstens 20 mm aufweisen.
 7. Verbundpanzerungsplatte nach einem der vorangehenden Ansprüche, wobei ein jedes der Pellets (2, 20, 30, 30') aus einem Keramikmaterial gebildet ist, das ausgewählt ist aus der Gruppe bestehend aus gesintertem Oxid, Nitriden, Karbiden und Boriden von Aluminiumoxid, Magnesium, Zirkonium, Wolfram, Molybdän, Titan und Silica.
 8. Verbundpanzerungsplatte nach einem der vorangehenden Ansprüche, wobei ein jedes der Pellets (2, 20, 30, 30') aus einem Material gebildet ist, das ausgewählt ist aus der Gruppe bestehend aus Aluminiumoxid, Borkarbid, Bornitrid, Titandiborid, Siliziumkarbid, Siliziumoxid, Siliziumnitrid, Magnesiumoxid, Siliziumaluminiumoxynitrid und Gemischen davon.
 9. Verbundpanzerungsplatte nach Anspruch 2 oder einem davon abhängigen Anspruch, wobei das verfestigte elastische Material und die Platte elastisch sind.
 10. Verbundpanzerungsplatte nach einem der vorangehenden Ansprüche, **dadurch gekennzeichnet, dass** ein Kanal (40) in einer Vielzahl der Pellets (30') vorgesehen ist, um ein Flächengewicht derselben zu reduzieren.

11. Verbundpanzerungsplatte nach Anspruch 10, wobei der Kanal (40) ein Volumen von bis zu 25 % des Pellets (30') einnimmt.
12. Mehrlagige Panzerungsplatte, umfassend eine äußere, Aufprall aufnehmende Lage, die durch eine Verbundpanzerungsplatte nach einem der vorangehenden Ansprüche gebildet ist, um ein aufprallendes Hochgeschwindigkeitsgeschoss zu verformen und zerschellen zu lassen, und eine innere Lage benachbart zu der äußeren Lage und umfassend ein ballistisches Material zum Absorbieren der verbleibenden kinetischen Energie von den Fragmenten.
13. Mehrlagige Panzerungsplatte nach Anspruch 12, wobei das ballistische Material Dyneema (TM), Kevlar (TM), Aluminium, Stahl, Titan oder S2 ist.
14. Verwendung einer Verbundpanzerungsplatte nach einem der Ansprüche 1 bis 11 als einen ballistischen Schutz für eine starre Panzerungsplatte.

Revendications

1. Plaque de blindage composite pour absorber et dissiper de l'énergie cinétique provenant projectiles à grande vitesse, la plaque comprenant une couche unique de pastilles (2, 20, 30, 30'), dans laquelle chaque pastille est constituée d'un matériau céramique et a une partie de corps (4, 24, 34) avec une surface de section transversale sensiblement géométrique, la surface de section transversale géométrique ayant un axe de symétrie, chaque dite pastille ayant des première et seconde faces d'extrémité (6, 8, 26, 28, 36, 38) faisant saillie, respectivement, à partir des extrémités opposées de la partie de corps (4, 24, 34) et chaque face d'extrémité (6, 8, 26, 28, 36, 38) ayant une surface de section transversale décroissante vers l'extérieur, la seconde face d'extrémité (8, 28, 38) étant sphérique et ayant une hauteur inférieure à 15 % du diamètre de la partie de corps, la première face d'extrémité (6, 26, 36) ayant une hauteur supérieure à la hauteur de la seconde face d'extrémité, les pastilles étant fixées et maintenues en forme de plaque par un matériau élastique solidifié, sensiblement à l'intérieur du matériau élastique solidifié, de sorte que les pastilles (2, 20, 30, 30') soient liées en une pluralité de rangées et colonnes espacées, les pastilles (2, 20, 30, 30') étant sensiblement entièrement incorporées au matériau élastique solidifié, dans laquelle le matériau élastique solidifié et la plaque sont élastiques, dans laquelle une majorité de chacune des pastilles (2, 20, 30, 30') est en contact direct avec six pastilles adjacentes dans la même couche pour fournir un confinement latéral réciproque entre elles, dans laquelle la seconde face d'extrémité (8, 28, 38) de chaque

couche est sensiblement opposée à une surface principale externe de réception d'impacts de la plaque et à première face d'extrémité (6, 26, 36) de chaque pastille est une face d'extrémité de réception d'impacts.

2. Plaque de blindage composite comprenant une pluralité de pastilles (2, 20, 30, 30') disposées en une couche et incorporées à un matériau élastique solidifié, dans laquelle chaque pastille est constituée d'un matériau céramique et a une partie de corps (4, 24, 34) avec une surface de section transversale sensiblement géométrique, la surface de section transversale géométrique ayant un axe de symétrie, chaque dite pastille ayant des première et seconde faces d'extrémité (6, 8, 26, 28, 36, 38) faisant saillie, respectivement, à partir des extrémités opposées de la partie de corps (4, 24, 34) et chaque face d'extrémité (6, 8, 26, 28, 36, 38) ayant une surface de section transversale décroissante vers l'extérieur, la seconde face d'extrémité (8, 28, 38) étant sphérique et ayant une hauteur inférieure à 15 % du diamètre de la partie de corps, la première face d'extrémité (6, 26, 36) ayant une hauteur supérieure à la hauteur de la seconde face d'extrémité, chaque partie de corps de pastille ayant un axe et une section transversale géométrique constante normale par rapport à l'axe, dans laquelle la section transversale constante a un axe de symétrie, chaque pastille (2, 20, 30, 30') en contact avec des pastilles adjacentes au niveau des parties de corps respectives (4, 24, 34) et les secondes faces d'extrémité (8, 28, 38) étant sensiblement opposées à une surface principale externe de réception d'impacts de la plaque, dans laquelle la hauteur de chaque seconde face d'extrémité est la hauteur de la seconde face d'extrémité le long de l'axe de la partie de corps correspondant, et dans laquelle chaque première face d'extrémité (6, 26, 36) est une face d'extrémité de réception d'impacts.
3. Plaque de blindage composite selon la revendication 1 ou 2, dans laquelle pour chaque seconde face d'extrémité (8, 28), le rapport D/R entre le diamètre D de la partie de corps (8, 24) de la pastille (2, 20) et le rayon R de la courbure de la seconde face d'extrémité (8, 28) est entre 0,28:1 et 0,639:1.
4. Plaque de blindage composite selon une quelconque revendication précédente, dans laquelle une majorité des premières faces d'extrémité (6, 6, 36) est courbée de manière convexe et orientée de façon à faire sensiblement face à la surface principale externe de réception d'impacts de la plaque.
5. Plaque de blindage composite selon une quelconque revendication précédente, dans laquelle les pastilles (2, 20, 30, 30') ont au moins un axe d'au

moins 9 mm.

6. Plaque de blindage composite selon la revendication 5, dans laquelle les pastilles (2, 20, 30, 30') ont au moins un axe d'au moins 20 mm.

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7. Plaque de blindage composite selon une quelconque revendication précédente, dans laquelle chacune desdites pastilles (2, 20, 30, 30') est constituée d'un matériau céramique sélectionné dans le groupe constitué par l'oxyde fritté, les nitrures, les carbures et les borures d'alumine, le magnésium, le zirconium, le tungstène, le molybdène, le titane et le silice.

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8. Plaque de blindage composite selon une quelconque revendication précédente, dans laquelle chaque dite pastille (2, 20, 30, 30') est constituée d'un matériau sélectionné dans le groupe constitué par l'alumine, le carbure de bore, la niture de bore, la diborure de titane, le carbure de silicium, l'oxyde de silicium, la niture de silicium, l'oxyde de magnésium, l'oxyniture d'aluminium-silicium et mélanges de ceux-ci.

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9. Plaque de blindage composite selon la revendication 2 ou toute revendication qui en dépend, dans laquelle le matériau élastique solidifié et ladite plaque sont élastiques.

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10. Plaque de blindage composite selon une quelconque revendication précédente **caractérisée en ce qu'un canal (40) est fourni dans une pluralité desdites pastilles (30')** pour réduire le poids par surface de celles-ci.

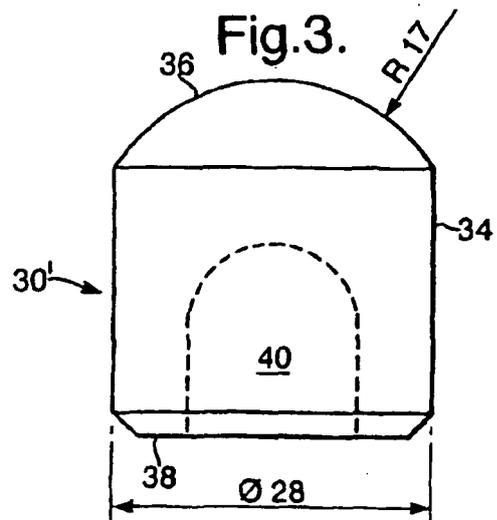
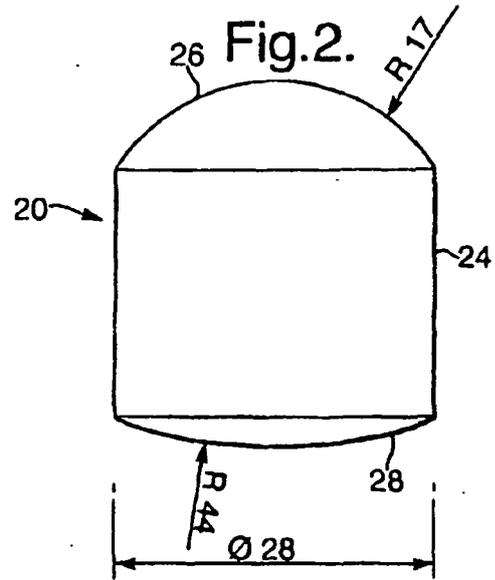
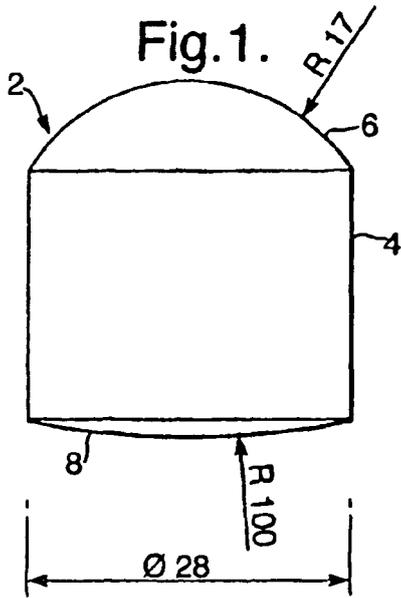
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11. Plaque de blindage composite selon la revendication 10, dans laquelle ledit canal (40) occupe un volume allant jusqu'à 25 % de ladite pastille (30').

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12. Panneau de blindage multicouche, comprenant une couche externe de réception d'impacts formée par une plaque de blindage composite selon l'une quelconque des revendications précédentes pour déformer et briser un projectile à grande vitesse causant un impact, et une couche interne adjacente à la couche externe et comprenant un matériau balistique pour absorber l'énergie cinétique restante desdits fragments.

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13. Panneau de blindage multicouche selon la revendication 12, dans lequel le matériau balistique est en Dyneema (TM), Kevlar (TM), aluminium, acier, titane ou S2.

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14. Utilisation d'une plaque de blindage composite selon l'une quelconque des revendications 1 à 11, en tant que protection balistique pour une plaque de blindage rigide.

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REFERENCES CITED IN THE DESCRIPTION

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