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(54) COMPOSITE ARMOR PLATE

VERBUNDPANZERPLATTE

BLINDAGE COMPOSITE

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Description

[0001] The present invention relates to composite armor plates and panels. More particularly, the invention relates to an armored plate which may be worn to provide the user with lightweight ballistic protection, as well as to armored plates for providing ballistic protection for light and heavy mobile equipment and vehicles against high-speed projectiles or fragments.

[0002] In US patent 5,763,813 there is described a composite armor plate for absorbing and dissipating kinetic energy from high velocity, armor-piercing projectiles, said plate comprising 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 superposed rows, characterized in that the pellets have an Al_20_3 content of at least 85%, preferably at least 93%, and a specific gravity of at least 2.5, the majority of the pellets each have at least one axis in the range of about 3-12 mm, and are bound by said solidified material in a single internal layer of superposed rows, wherein a majority of each of said pellets is in direct contact with at least 4 adjacent pellets, the total weight of said plate does not exceed 45 kg/m^2 and said solidified material and said plate are elastic.

[0003] In European patent application Serial No. 98301769.0 there is described and claimed a composite armor plate for absorbing and dissipating kinetic energy from high velocity, armor-piercing projectiles, said plate comprising 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, characterized in that the pellets have an Al_20_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 and are bound by said solidified material in a single internal layer of adjacent rows, wherein a majority of each of said pellets is in direct contact with at least 4 adjacent pellets, and said solidified material and said plate are elastic.

[0004] In WO-A-98/15796, which discloses the preamble of claim 1, 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 DIR 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.

[0005] 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/m^2.

[0006] 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, since the weight of standard armor to withstand such projectile is such as to impede the mobility and performance of such vehicles.

[0007] A second consideration is cost. Overly complex armor arrangements, particularly those depending entirely on synthetic fibers, can be responsible for a notable proportion of the total vehicle cost, and can make its manufacture non-profitable.

[0008] 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.

[0009] 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.

[0010] 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 aluminium; 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.

[0011] 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.

[0012] Ceramic materials are nonmetallic, inorganic solids having a crystalline or glassy structure, and have many useful physical properties, including resistance to heat, abrasion and compression, high rigidity, low weight in comparison with steel, and outstanding chemical stability. Such properties have long drawn the attention of armor designers, and solid ceramic plates, in thicknesses ranging from 7 mm. for personal protection to 30 mm. for heavy military vehicles, are commercially available for such use.

[0013] Much research has been devoted to improving the low tensile and low flexible strength and poor fracture toughness of ceramic materials; however, these remain the major drawbacks to the use of ceramic plates and other large components which can crack and/or shatter in response to the shock of an incoming projectile.

[0014] Light-weight, flexible armored articles of clothing have also been used for many decades, for personal protection against fire-arm projectiles and projectile splinters. Examples of this type of armor are found in U.S. Patent No. 4,090,005. Such clothing is certainly valuable against low-energy projectiles, such as those fired from a distance of several hundred meters, but fails to protect the wearer against high-velocity projectiles originating at closer range and especially does not protect against armor-piercing projectiles. If made to provide such protection, the weight and/or cost of such clothing discourages its use. A further known problem with such clothing is that even when it succeeds in stopping a projectile the user may suffer injury due to indentation of the vest into the body, caused by too small a body area being impacted and required to absorb the energy of a bullet.

[0015] A common problem with prior art ceramic armor concerns damage inflicted on the armor structure by a first projectile, whether stopped or penetrating. Such damage weakens the armor panel, and so allows penetration of a following projectile, impacting within a few centimeters of the first.

[0016] The present invention is therefore intended to obviate the disadvantages of prior art ceramic armor, and in a first embodiment to provide an armor plate which is effective against small-caliber fire-arm projectiles, yet is of light weight, i.e, having a weight of less than 45 kg/m^2 (which is equivalent to about 9 lbs/ft^2) and low bulk.

[0017] A further object of the invention is to provide an armor plate or panel which is particularly effective in arresting a plurality of armor-piercing projectiles impacting upon the same general area of the panel.

[0018] The armor plates described in US Patent 5,763,813 and European application 98301769.0 are made using ceramic pellets made substantially entirely of aluminum oxide. In WO-A-98/15796 the ceramic bodies are of substantially cylindrical shape having at least one convexly-curved end-face, and are preferably made of aluminium oxide.

[0019] However, it has now been found that the improved properties of the plates described in the above patent applications is as much a function of the configuration of the pellets, which are of regular geometric form (for example, the pellets may be spherical or ovoidal, or of regular geometric cross-section, such as square, hexagonal, octagonal, or circular), 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 in the same layer to provide mutual lateral confinement therebetween. As a result, composite armor plates superior to those available in the prior art can be manufactured using glass pellets which have a specific gravity of only 2, or pellets made of sintered refractory materials or ceramic materials having a specific gravity equal to or below that of aluminium 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.

[0020] Thus, sintered oxides, nitrides, carbides and borides of magnesium, zirconium, tungsten, molybdenum, titanium and silica can be used and especially preferred for use in the present invention are pellets selected from the group consisting of glass, boron carbide, titanium diboride, silicon carbide, magnesium oxide, silicon aluminum oxynitride in both its alpha and beta forms and mixtures thereof.

[0021] With increase in specific gravity the stopping power of the plates increases so that those plates utilizing pellets of higher specific gravity are also useful for absorbing and dissipating kinetic energy from high-velocity armor-piercing bullets.

[0022] In accordance with a first aspect of the invention, there is provided a composite armor plate according to claim 1.

[0023] As stated hereinbefore, in WO-A-9 8/15796 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 however, as noted, the entire thrust of said specification is the use of cylindrical pellets having a specific diameter to radius ratio.

[0024] The solidified material retains elasticity upon hardening at the thickness used, thereby allowing curvature of the plate without cracking to match curved surfaces to be protected, including body surfaces, as well as elastic reaction of the plate to incoming projectiles to allow increased contact force between adjacent pellets at the point of impact.

[0025] In French Patent 2,711,782, there is described a steel panel reinforced with ceramic materials; however, due to the rigidity and lack of elasticity of the steel of said panel, said panel does not have the ability to deflect armor-piercing projectiles unless a 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.

[0026] It is further to be noted that the elasticity of the material used in preferred embodiments of the present invention serves, to a certain extent, to increase the probability that a projectile will simultaneously impact several pellets, thereby increasing the efficiency of the stopping power of the plate of the present invention.

[0027] In accordance with a first embodiment, there is provided a multi-layered armor panel, comprising an outer, impact-receiving layer formed by a composite armor plate according to the first or second aspect of the invention, for deforming and shattering an impacting high velocity projectile; and an inner layer adjacent to said outer layer, comprising an elastic material for absorbing the remaining kinetic energy from said fragments of said projectile.

[0028] In accordance with a second embodiment, there is provided a multi-layered armor panel, comprising an outer, impact-receiving layer formed by a composite armor plate according to the first and second aspect of the invention, for

deforming and shattering an impacting high velocity projectile; and an inner layer adjacent to said outer layer, said inner layer comprising a tough woven textile material for causing an asymmetric deformation of the remaining fragments of said projectile and for absorbing the remaining kinetic energy from said fragments, wherein said multi-layered panel is capable of stopping three projectiles fired sequentially at a triangular area of said multi-layered panel, wherein the height of said triangle is substantially equal to three times the length of the axis of said pellets.

[0029] As described, e.g., in U.S. Patent 5,361,678, composite armor plate comprising a mass of spherical ceramic balls distributed in an aluminium alloy matrix is known in the prior art. However, such prior art composite armor plate suffers from one or more serious disadvantages, 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 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, in which each of the pellets is in direct contact with at least four and preferably six adjacent pellets.

[0030] 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 displaced during casting of molten metal into interstices between the spheres.

[0031] In order to minimize such displacement, U.S. 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 the composite armor. It has been determined, however, that such a network of interlinked metal shells substantially increases the overall weight of the armored panel and decreases the stopping power thereof.

[0032] It is further to be noted that U.S. 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 armored panel and decreases the stopping power thereof, due to a billiard-like effect upon impact.

[0033] In U.S. Patents 3,523,057 and 5,134,725 there are described further armored panels incorporating ceramic and glass balls; however, said panels are flexible and it has been found that the flexibility of said panels substantially reduces their stopping strength upon impact, since the force of impact itself causes a flexing of said panels and a reduction of the supporting effect of adjacent constituent bodies on the impacted constituent body, due to the arrangement thereof in said patent. Thus, it will be noted that the teachings of U.S. Patent 5,134,725 is limited to an armor plate having a plurality of constituent bodies of glass or ceramic material which are arranged in at least two superimposed layers, which arrangement is similar to that seen-in US Patent 3,705,558. In addition, reference to Figures 3 and 4 of said patent show that pellets of a first layer do not contact pellets of the same layer and are only in contact with pellets of an adjacent layer and therefore do not benefit from the support of adjacent pellets in the same layer to provide mutual lateral confinement of the pellets, as taught in the present invention.

[0034] As will be realized, none of said prior art patents teaches or suggests the surprising and unexpected stopping power of a single layer of ceramic or glass pellets in direct contact with each other which, as will be shown hereinafter, successfully prevents penetration of fire arm projectiles despite the relative light weight of the plate incorporating said pellets.

[0035] Thus, it has been found that the novel armor of the present invention traps incoming projectiles between several pellets which are held in a single layer in mutual abutting and laterally-confining relationship. The relatively moderate size of the pellets ensures that the damage caused by a first projectile is localized and does not spread to adjoining areas, as in the case of ceramic plates.

[0036] Similarly and as demonstrated hereinafter, spherical glass pellets having a diameter of 10 mm were more than adequate to deal with mufti-impacts of soft metal component 5.56 and 7.62 mm projectiles.

[0037] 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. The pellets used are either spheres or other regular geometric shapes having at least one convexly-curved end face, said end face being oriented to substantially face in the direction of an outer impact receiving major surface of said plate and this form, when supported in a matrix of pellets, as shown, e.g. in the figures attached hereto, has been found to be significantly

better at resisting shattering than other pellet arrangements suggested in the prior art.

2. Flank contact. The impact causes projectile yaw and shattering, 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 matrix, and penetration is prevented.

[0038] An additional preferred embodiment according to the present invention is one wherein the ceramic material is SiAlON in its alpha structure of $Si_{6-z}Al_zO_zN_{8-z}$, in which "z" is a substitution coefficient of Al and O in the Si_3N_4 and the "beta structure" of the formula $Me_{m/val}Si_{12-(m+n)}Al_{m+n}O_nN_{16-n}$, wherein Me is a metal such as Li, Mg, Ca, Y, and lanthanide's, m and n are substitution coefficients and val is the valency of the metal..

[0039] The invention will now be described in connection with certain preferred embodiments with reference to the following illustrative figure so that it may be more fully understood.

[0040] With reference now to the figure 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.

[0041] In the drawing Fig. 1 is a cross-sectional side view of a two-layered armor panel which is not according to the invention.

[0042] There is seen in Fig. 1 a composite armor plate 10 for absorbing and dissipating kinetic energy from fire-arm projectiles 12, said plate comprising a single internal layer of spherical glass pellets 14, said pellets being arranged in a single layer of adjacent rows, wherein each of a majority of said pellets is in direct contact with at least 4 adjacent pellets. As seen, the entire array of pellets is bound in said single layer of a plurality of adjacent rows by solidified epoxy 16 and said plate 10 is further provided with an inner backing layer 18 made of DYNEEMA® or of similar material, to form a multi-layered armored panel 20.

[0043] Tables 1 and 2 are reproductions of test reports relating to epoxy-bound multi-layer panels as described above with reference to Fig. 1. Each of the panels had dimensions of 14" x 14" and had a backing layer 18 made of DYNEEMA® 10 mm thick..

[0044] The first panel was impacted by a series of three soft-nosed component 7.62 mm projectiles fired at 0° elevation and at a distance of 50 ft. from the target.

[0045] None of the 3 projectiles penetrated the panel.

[0046] The second panel was impacted by a series of six soft-nosed component 5.56 mm projectiles, also fired at 0 elevation and at a distance of 50 ft. from the target.

[0047] None of the 6 projectiles penetrated the panel.

Table 1

H,P. WHITE LABORATORY. INC.

DATA RECORD

-BALLISTIC RESISTANCE TESTS

Date Rec'd :	04-27-98	Job No. :7592-02
Via :	Hand carried	Test Date: 04-27-98
Returned :	Hand carried	Customer :R & D ETZION
File (HPWLI) :	RD-1.PIN	

TEST PANEL

Description:	PROPRIETARY		
Manufacturer:	R & D ETZION	Sample No. :	12
Size :	PT.10X12 VT. 14X14 in.	Weight :	PT. 5.18, VT. 1.97 lbs.
Thicknesses:	na	Hardness :	na
Avg. Thick.:	na	Plies/Laminates:	NA

(continued)

AMMUNITION			
(1): 7.62x51 mm	M80 BALL 149.0gr	Lot No.:	WINCHESTER WCC90B001-001
(2):		Lot No.:	
(3):		Lot No.:	
(4):		Lot No.:	

SET-UP			
Vel. Screens :	6.5 ft. & 9.5 ft.	Range to Target:	50.0 ft.
Shot Spacing :	PER CUSTOMER REQUEST	Range Number :	1
Barrel NoJGun:	062	Backing material:	5.5" CLAY/PLYWOOD
Obliquity :	0 deg.	Target to Wit. :	0.0in.
Witness Panel :	CLAY	Conditioning :	DRY @71 Deg. F.

APPLICABLE STANDARDS OR PROCEDURES

(1): PER CUSTOMER REQUEST

(2):

(3):

Shot No.	Ammo.	Time sx10-5	Velocity ft/s	Time sx10-5	Velocity ft/s	Avg.Vel. ft/s	Penetration	Footnotes
1							None	DEF. 42X82 mm
2							None	DEF. 43X86 mm
3							None	DEF. 37x83 mm

FOOTNOTES:	REMARKS: Local BP-30.08 in. Hg. Temp.-71.0 F, RH-42%
	Gunner/Recorder: BLACK/THOMAS

Table 2

H.P. WHITE LABORATORY, INC.

DATA RECORD

-BALLISTIC RESISTANCE TESTS

Date Rec'd :	04-27-98	Job No.:	7592-02
Via:	Hand carried	Test Date:	04-28-98
Returned :	Hand carried	Customer:	R & D ETZION
File (HPWLI) :	RD-15.PIN		

TEST PANEL			
Description :	PROPRIETARY		
Manufacturer:	R & D ETZION	Sample No. :	8
Size :	PT.10X12, VT. 14X14 in.	Weight :	PT. 7.20, VT. 1.94 lbs.
Thicknesses:	na	Hardness :	na
Avg. Thick. :	na	Plies/Laminates: NA	

AMMUNITION			
(1):	5.56x45mm M855 BALL 62.0gr	Lot No.:	FNB83G001L002
(2):		Lot No.:	
(3):		Lot No.:	

(continued)

AMMUNITION			
(4):		Lot No.:	
SET-UP			
Vel. Screens :	6.5 ft. & 9.5 ft.	Range to Target:	50.0 ft.
Shot Spacing :	PER CUSTOMER REQUEST	Range Number :	1
Barrel No./Gun:	038	Backing material:	5.5" CLAY/PLYWOOD
Obliquity :	0 deg.	Target to Wit. :	0.0in.
Witness Panel :	CLAY	Conditioning :	DRY @68 Deg. F.

APPLICABLE STANDARDS OR PROCEDURES

(1): PER CUSTOMER REQUEST
(2):
(3):

Shot No.	Ammo.	Time sx10-5	Velocity ft/s	Time sx10-5	Velocity ft/s	Avg. Vel. ft/s	Penetration	Footnotes
1							None	DEF. 12x65mm
2							None	DEF. 14x61mm
3							None	DEF. 12x55mm
4							None	OEF. 10x54mm
5						None	None	DEF. 13x62mm
6							None	DEF. 14x61

FOOTNOTES:

REMARKS:
Local BP-30.06 in. Hg. Temp.-68.0 F, RH-48%

Gunner/Recorder. BLACK/THOMAS

[0048] As will be noted, spherical glass pellets, when arranged in a single layer according to the present invention, enable the preparation of a composite armor plate which can withstand multiple impacts in a relatively small area, which multi-impact protection was not available with prior art amour of comparable weight

[0049] Considering that SiAlON is lighter in weight than aluminum oxide and has a surprisingly greater shattering strength, it is ideally suited for use in the composite armor plates of the present invention.

[0050] It will be evident to those skilled in the art that the invention is not limited to the details of the foregoing illustrated embodiments and that the present invention may be embodied in other specific forms without departing from the scope of the invention as defined by the appended claims.

Claims

1. A composite armor plate (10) for absorbing and dissipating kinetic energy from high velocity projectiles; said plate comprising a single internal layer of pellets (14) which are directly bound and retained in plate form by a solidified material (16) such that the pellets are bound in a plurality of adjacent rows; said solidified material (16) and said plate being elastic; the pellets (14) having a specific gravity of at least 2; the majority of the pellets (14) each having at least one axis having a length in the range of from 6 to 19mm and being bound by said solidified material (16) in said single internal layer of adjacent rows such that each of a majority of said pellets (14) is in direct contact with six adjacent pellets (14) in the same layer to provide mutual lateral confinement therebetween; said pellets (14) each having a major axis and a substantially regular geometric form with at least one convexly-curved end face oriented to substantially face in the direction of an outer impact-receiving major surface of said plate; wherein said pellets (14) are arranged with their major axes substantially parallel to each other and oriented substantially per-

pendicularly relative to the outer impact-receiving major surface of said plate, and wherein the weight of the plate does not exceed 45 kg/m^2; wherein said pellets are made of a material selected from the group consisting of glass, sintered refractory material, and ceramic material other than aluminium oxide; **characterised in that** each pellet (14) is other than an excluded body hereafter defined; wherein the excluded body is cylindrical and has at least one convexly-curved end face, the ratio D/R between the diameter D of said cylindrical excluded body and the radius R of curvature of said at least one convexly-curved end face of said cylindrical excluded body is at least 0.64:1; and **in that** the solidified material is a thermoplastic polymer.

2. A composite armor plate (10) according to claim 1, wherein said pellets (14) are spherical.

3. A composite armor plate (10) as claimed in claim 1 for absorbing and dissipating kinetic energy from high velocity armor piercing-projectiles, wherein said pellets (14) are made of a material selected from the group consisting of boron carbide, titanium diboride, silicon carbide, magnesium oxide, silicon aluminium oxynitride and mixtures thereof.

4. A composite armor plate (10) as claimed in any of the preceding claims, wherein each of a majority of said pellets (14) along an edge of the plate is in direct contact with four adjacent pellets and internal pellets (14) in said. plurality of rows within said plate are in direct contact with six adjacent pellets (14).

5. A composite armor plate (10) as claimed in claim 1, wherein said pellets (14) are made of silicon aluminium oxynitride.

6. A multi-layered armor panel (20), comprising:

an outer, impact-receiving layer formed by composite armor plate (10) according to any preceding claim, for deforming and shattering an impacting high velocity projectile; and
an inner layer (18) adjacent to said outer layer, comprising an elastic material for absorbing the remaining kinetic energy from fragments of said projectile.

7. A multi-layered armor panel (20) according to claim 6, wherein the elastic material (18) is a woven textile material.

8. A multi-layered armor panel (20), comprising:

an outer, impact-receiving layer formed by a composite armor plate (10) according to any one of claims 1-5, for deforming and shattering an impacting high velocity projectile; and
an inner layer (18) adjacent to said outer later, said inner layer (18) comprising a tough woven textile material for causing an asymmetric deformation of the remaining fragments of said projectile and for absorbing the remaining kinetic energy from said fragments,

wherein said multi-layered panel (20) is capable of stopping three projectiles fired sequentially at a triangular area of said multi-layered panel, wherein the height of said triangle is substantially equal to three times the length of the axis of said pellets.

9. A multi-layered armor panel (20) according to claim 8, wherein the inner layer is made of Kevlar®.

10. A multi-layered armor panel (20) according to claim 8, comprising a further backing layer of aluminium.

11. A multi-layered armor panel (20) according to claim 8, wherein the inner later comprises multiple layers of polyamide netting.

12. A multi-layered armor panel (20) comprising:

an outer, impact-receiving layer formed by a composite armor plate (10) according to any one of claims 1-5, for deforming and shattering an impacting high velocity projectile; and
an inner layer (18) adjacent to said outer layer, said inner layer (18) being made of Dyneema for causing an asymmetric deformation of the remaining fragments of said projectile and for absorbing the remaining kinetic energy from said fragments,

wherein said multi-layered panel (20) is capable of stopping three projectiles fired sequentially at a triangular area of said multi-layered panel, wherein the height of said triangle is substantially equal to three times the length of the

axis of said pellets.

Patentansprüche

1. Verbundpanzerplatte (10) zur Absorption und Dissipation kinetischer Energie von Hochgeschwindigkeitsprojektilen; wobei die Platte eine einzelne Innenschicht aus Kügelchen (14) umfasst, die direkt mit der aus einem fest gewordenen Material (16) gebildete Platte verbunden sind und von dieser gehalten werden, so dass die Kügelchen zu mehreren nebeneinander liegenden Reihen verbunden sind; das fest gewordene Material (16) und die Platte elastisch ausgebildet sind; die Kügelchen (14) ein spezifisches Gewicht von wenigstens 2 aufweisen; die Mehrheit der Kügelchen (14) jeweils mindestens eine Achse mit einer Länge zwischen 6 und 9 mm aufweisen und mit dem fest gewordenen Material (16) in der einzelnen Innenschicht aus benachbarten Reihen verbunden sind, so dass sich jedes einer Mehrheit der Kügelchen (14) in direktem Kontakt mit sechs angrenzenden Kügelchen (14) in derselben Schicht befindet, um eine gegenseitige laterale Abgrenzung untereinander zu bilden; die Kügelchen (14) jeweils eine Hauptachse und eine im Wesentlichen gleichmäßige geometrische Form mit wenigstens einer konvex gebogenen Endfläche aufweisen, die so ausgerichtet ist, dass sie im wesentlichen der Richtung einer äußeren Stoßaufnahmehauptfläche der Platte zugewandt ist; wobei die Hauptachsen der Kügelchen (14) im Wesentlichen parallel zueinander angeordnet und die Kügelchen relativ zu der äußeren Stoßaufnahmehauptoberfläche der Platte im Wesentlichen rechtwinklig ausgerichtet sind; und wobei das Gewicht der Platte 45 kg/m^2 nicht übersteigt, wobei die Kügelchen aus einem Material gebildet sind, das aus der Gruppe, die Glas, gesintertes, feuerfestes Material, und ein anderes Keramikmaterial als Aluminiumoxid umfasst, auswählbar ist; **dadurch gekennzeichnet, dass** jedes Kügelchen (14) anders als ein im Nachfolgenden definierter ausgeschlossener Körper ausgebildet ist, wobei der ausgeschlossene Körper eine zylindrische Form und wenigstens eine konvex gebogenen Endfläche aufweist, und das Verhältnis D/R des Durchmessers D des zylindrischen, ausgeschlossenen Körpers zu dem Radius R der Krümmung der wenigstens einen konvex gebogenen Endfläche des zylindrischen ausgeschlossenen Körpers wenigstens 0,64:1 beträgt; und dass das fest gewordene Material ein thermoplastisches Polymer ist.

2. Verbundpanzerplatte (10) nach Anspruch 1, wobei die Kügelchen (14) kugelförmig ausgebildet sind.

3. Verbundpanzerplatte (10) zur Absorption und Dissipation kinetischer Energie von Hochgeschwindigkeitsprojektilen nach Anspruch 1, wobei die Kügelchen (14) aus einem Material gebildet sind, das aus der Gruppe, die Borcarbid, Titandiborid, Siliziumcarbid, Magnesiumoxid, Silizium-Aluminium-Oxinitrid und Mischungen daraus umfasst, auswählbar ist.

4. Verbundpanzerplatte (10) nach einem der vorangehenden Ansprüche, wobei jedes einer Mehrheit der Kügelchen (14) entlang einer Plattenkante jeweils in direktem Kontakt mit vier angrenzenden Kügelchen ist und innere Kügelchen (14) in den mehreren Reihen innerhalb der Platte in direktem Kontakt mit sechs angrenzenden Kügelchen (14) sind.

5. Verbundpanzerplatte (10) nach Anspruch 1, wobei die Kügelchen (14) aus Silizium-Aluminium-Oxinitrid gebildet sind.

6. Mehrschichtige Panzerplatte (20) umfassend:

   eine Stoßaufnahmeaußenschicht, die aus einer Verbundpanzerplatte (10) gemäß einem der vorangehenden Anspruch gebildet ist, zur Verformung und Zertrümmerung eines aufschlagenden Hochgeschwindigkeitsprojektils; und
   eine Innenschicht (18), die neben der Außenschicht angeordnet ist und ein elastisches Material zur Absorption der restlichen kinetischen Energie von Projektilfragmenten umfasst.

7. Mehrschichtige Panzerplatte (20) nach Anspruch 6, wobei das elastische Material (18) ein Webstoffmaterial umfasst.

8. Mehrschichtige Panzerplatte (20) umfassend:

   eine Stoßaufnahmeaußenschicht, die aus einer Verbundpanzerplatte (10) gemäß einem der Ansprüche 1 - 5 gebildet ist, zur Verformung und Zertrümmerung eines aufschlagenden Hochgeschwindigkeitsprojektils; und
   eine Innenschicht (18), die neben der Außenschicht angeordnet ist, wobei die Innenschicht (18) ein grobes Webstoffmaterial umfasst, um eine asymmetrische Verformung der restlichen Projektilfragmente hervorzurufen und die restliche kinetische Energie der Fragmente zu absorbieren,

wobei die mehrschichtige Platte (20) drei Projektile aufhalten kann, die nacheinander auf eine dreieckige Fläche der mehrschichtigen Platte abgefeuert werden, wobei die Höhe des Dreiecks im Wesentlichen drei Mal der Achsenlänge der Kügelchen entspricht.

9. Mehrschichtige Panzerplatte (20) nach Anspruch 8, wobei die Innenschicht aus Kevlar® gebildet ist.

10. Mehrschichtige Panzerplatte (20) nach Anspruch 8, das eine weitere Verstärkungsschicht aus Aluminium aufweist.

11. Mehrschichtige Panzerplatte (20) nach Anspruch 8, wobei die Innenschicht mehrere Schichten aus Polyamidgewebe aufweist.

12. Mehrschichtige Panzerplatte (20) umfassend:

eine Stoßaufnahmeaußenschicht, die aus einer Verbundpanzerplatte (10) gemäß einem der Ansprüche 1 - 5 gebildet ist, zur Verformung und Zertrümmerung eines aufschlagenden Hochgeschwindigkeitsprojektils; und
eine Innenschicht (18), die neben der Außenschicht angeordnet ist, wobei die Innenschicht (18) Dyneema umfasst, um eine asymmetrische Verformung der restlichen Projektilfragmente hervorzurufen und die restliche kinetische Energie der Fragmenten zu absorbieren,
wobei die mehrschichtige Platte (20) drei Projektile aufhalten kann, die nacheinander auf eine dreieckige Fläche der mehrschichtigen Platte abgefeuert werden, wobei die Höhe des Dreiecks im Wesentlichen drei Mal der Achsenlänge der Kügelchen entspricht.

Revendications

1. Plaque de blindage composite (10) destinée à absorber et dissiper l'énergie cinétique de projectiles à grande vitesse : ladite plaque comportant une unique couche interne d'éléments (14) qui sont directement liés et retenus sous forme de plaque par une matière solidifiée (16) de telle sorte que les éléments sont liés en une multiplicité de rangées adjacentes ; ladite matière solidifiée (16) et ladite plaque étant élastiques ; les éléments (14) ayant une densité d'au moins 2 ; la majorité des éléments (14) ayant chacun au moins un axe ayant une longueur dans la plage de 6 à 19 mm et étant liée par ladite matière solidifiée (16) dans ladite couche interne unique de rangées adjacentes de telle sorte que chaque élément d'une majorité desdits éléments (14) est en contact direct avec six éléments (14) adjacents dans la même couche afin d'assurer un confinement latéral mutuel entre eux ; lesdits éléments (14) ayant chacun un grand axe et une forme géométrique sensiblement rectangulaire avec au moins une face d'extrémité courbe de manière convexe orientée pour faire sensiblement face dans la direction d'une surface principale extérieure de réception d'impact de ladite plaque ; dans laquelle lesdits éléments (14) sont disposés avec leurs grands axes sensiblement parallèles l'un à l'autre et orientés de manière sensiblement perpendiculaire par rapport à la surface principale extérieure de réception d'impact de ladite plaque ; et dans laquelle le poids de la plaque ne dépasse pas 45 kg/m^2 ; dans laquelle lesdits éléments sont fabriqués dans une matière choisie dans le groupe se composant du verre, d'une matière réfractaire frittée, et d'une matière céramique autre que de l'oxyde d'aluminium ; caratérisée en ce que chaque élément (14) est autre qu'un corps exclu défini ci-après ; le corps exclu étant cylindrique et ayant au moins une face d'extrémité courbe de manière convexe, le rapport D/R entre le diamètre D dudit corps exclu cylindrique et le rayon R de courbure de ladite au moins une face d'extrémité courbe de manière convexe dudit corps exclu cylindrique étant d'au moins 0,64 : 1 ; et en ce que la matière solidifiée est un polymère thermoplastique.

2. Plaque de blindage composite (10) selon la revendication 1, dans laquelle lesdits éléments (14) sont sphériques.

3. Plaque de blindage composite (10) selon la revendication 1 destinée à absorber et dissiper l'énergie cinétique de projectiles de perforation de blindage à grande vitesse, dans laquelle lesdits éléments (14) sont fabriqués dans une matière choisie dans le groupe composé du carbure de bore, du diborure de titane, du carbure de silicium, de l'oxyde de magnésium, de l'oxynitrure de silicium et d'aluminium et de mélanges de ceux-ci.

4. Plaque de blindage composite (10) selon l'une quelconque des revendications précédentes, dans laquelle chaque élément d'une majorité desdits éléments (14) le long d'un bord de la plaque est en contact direct avec quatre éléments adjacents et des éléments internes (14) dans ladite multiplicité de rangées à l'intérieur de ladite plaque sont en contact direct avec six éléments (14) adjacents.

5. Plaque de blindage composite (10) selon la revendication 1, dans laquelle lesdits éléments (14) sont fabriqués en

oxynitrure de silicium et d'aluminium.

6. Panneau de blindage multicouche (20), comportant :

une couche extérieure de réception d'impact formée par une plaque de blindage composite (10) selon l'une quelconque des revendications précédentes, destinée à déformer et disperser un projectile d'impact à grande vitesse ; et
une couche intérieure (18) adjacente à ladite couche extérieure, comportant une matière élastique destinée à absorber l'énergie cinétique restante de fragments dudit projectile.

7. Panneau de blindage multicouche (20) selon la revendication 6, dans lequel la matière élastique (18) est une matière textile tissée.

8. Panneau de blindage multicouche (20), comportant :

une couche extérieure de réception d'impact formée par une plaque de blindage composite (10) selon l'une quelconque des revendications 1-5, destinée à déformer et disperser un projectile d'impact à grande vitesse ; et une couche intérieure (18) adjacente à ladite couche extérieure, ladite couche intérieure (18) comportant une matière textile tissée solide destinée à provoquer une déformation asymétrique des fragments restants dudit projectile et destinée à absorber l'énergie cinétique restante desdits fragments,
dans lequel ledit panneau multicouche (20) est capable d'arrêter trois projectiles tirés de manière séquentielle au niveau d'une zone triangulaire dudit panneau multicouche, la hauteur dudit triangle étant sensiblement égale à trois fois la longueur de l'axe desdits éléments.

9. Panneau de blindage multicouche (20) selon la revendication 8, dans lequel la couche intérieure est fabriquée en Kevlar®.

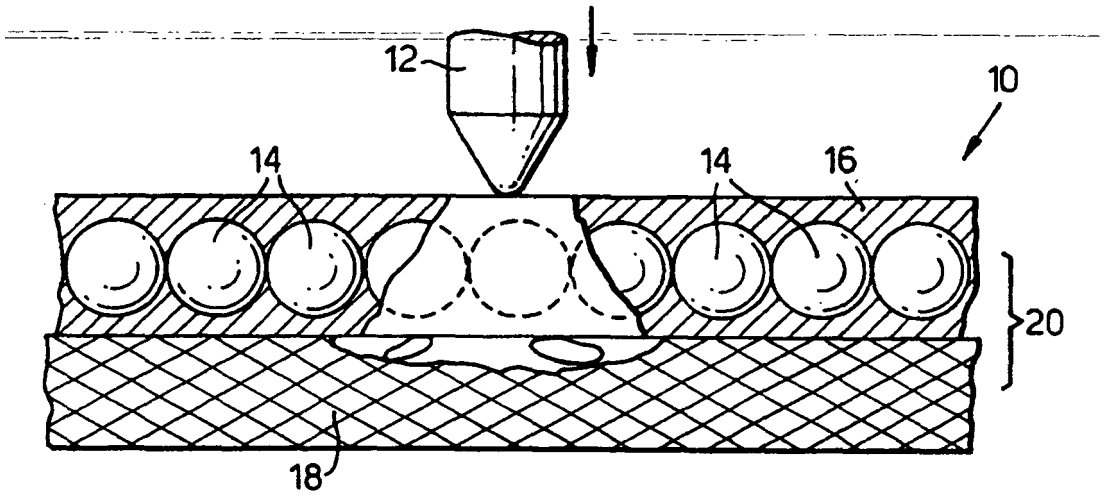
10. Panneau de blindage multicouche (20) selon la revendication 8, comportant une couche de support supplémentaire en aluminium.

11. Panneau de blindage multicouche (20) selon la revendication 8, dans lequel la couche intérieure comporte de multiples couches de filet en polyamide.

12. Panneau de blindage multicouche (20), comportant :

une couche extérieure de réception d'impact formée par une plaque de blindage composite (10) selon l'une quelconque des revendications 1-5, destinée à déformer et disperser un projectile d'impact à grande vitesse ; et une couche intérieure (18) adjacente à ladite couche extérieure, ladite couche intérieure (18) étant fabriquée en Dyneema afin de provoquer une déformation asymétrique des fragments restants dudit projectile et afin d'absorber l'énergie cinétique restante desdits fragments,
ledit panneau multicouche (20) étant capable d'arrêter trois projectiles tirés de manière séquentielle au niveau d'une zone triangulaire dudit panneau multicouche, la hauteur dudit triangle étant sensiblement égale à trois fois la longueur de l'axe desdits éléments.

Fig.1.



REFERENCES CITED IN THE DESCRIPTION

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