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(54) **MULTI-BALLISTIC-IMPACT RESISTANT ARTICLE**

MEHRFACHBESCHUSS- UND SCHLAGSICHERER ARTIKEL

ARTICLE RÉSISTANT À UN IMPACT BALISTIQUE MULTIPLE

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Description

[0001] The present invention relates to a multi-ballistic-impact resistant article and to a process for manufacturing thereof, said article comprising a plurality of stacked monolayers, the monolayers containing at least one polyolefin tape, as described in US2008/0139071 A. The invention further relates to various products containing said article.

[0002] Multi- (or multiple) ballistic-impact, hereinafter also referred to as multi-hit, resistant articles are known in the art. EP 0 833 742 B1 discloses for example a ballistic resistant article containing a rigid panel comprising a compressed stack of monolayers, each monolayer containing unidirectionally reinforcing fibers or tapes and a plastic matrix material. The stack of monolayers was compressed to at least 98.0% of its theoretical maximum density. It was observed that the article of EP 0 833 742 B1 can withstand multiple hits or impacts from low caliber projectiles shot from weapons such as handguns loaded with 0.44 Magnum JHP bullets and even from AK-47 rifles loaded with 7.62 mm $\times$ 39 mm mild steel core bullets.

[0003] It was also observed that although effective against multiple impacts from low caliber projectiles, the known articles are less able to withstand multiple impacts from large caliber projectiles e.g. 20 mm Fragment Simulated Projectiles (FSP). Large caliber projectiles are heavy projectiles having a large volume of e.g. at least 3 cm^3 and a mass of e.g. at least 30 grams. For example, the standard 20 mm FSP as defined in STANAG 4569 (AEP 55, Volume 1, Ed. 1, Feb. 2005) is made of cold rolled annealed steel conforming to composition 4337H, 4340H or equivalent and with hardness value of HRC 30$\pm$2 after manufacturing, has a volume of about 7.4 cm^3 and a mass of 53.8 $\pm$ 0.26 g. For comparison, a low caliber 0.44 Magnum JHP bullet has a volume of about 1.4 cm^3 and a mass of about 15.6 g.

[0004] Other known articles which may be able to withstand multiple impacts from ballistic projectiles are known from WO 2010/003769. This document discloses a rigid article comprising a plurality of stacked monolayers, the monolayer containing polyolefin reinforcing elements such as fibers or tapes wherein said article is able to withstand at least two impacts from threats travelling at high speeds. However, the articles disclosed therein have considerable areal densities, i.e. areal densities of above 200 Kg/m^2. Therefore, although successful in defeating multiple impacts from ballistic projectiles, the articles of WO 2010/003769 are substantially heavy.

[0005] WO94/23263 describes an anti-ballistic composite comprising a stack of fibrous layers secured together, for example by stitching. A preferred embodiment comprises a fibrous girdle encompassing the stack of fibrous layers. Such an arrangement is said to provide good resistance to penetration. An aim of the present invention may thus be to provide a lightweight article, which has an optimum performance in terms of its ballistic resistance. A more particular aim of the present invention may be to provide a lightweight ballistic resistant article, which is able to withstand repeated impacts from large caliber projectiles, e.g. 20 mm FSP. An even more particular aim of the present invention may be to provide a lightweight ballistic resistant article, which is able to withstand repeated impacts from high velocity, large caliber projectiles, e.g. 20 mm FSP.

[0006] A multiple-ballistic-impact resistant article having an upper surface, a lower surface and lateral sides, said article comprising a plurality of stacked monolayers and at least part of the monolayers containing at least one polyolefin tape, said plurality of stacked monolayers has a total areal density of less than 200 Kg/m2, wherein the upper and/or lower face of at least a number of monolayers comprising at least one polyolefin tape have been subjected to a flame treatment, and wherein a first fibrous wrap encircles at least a portion of said upper surface, said lower surface and at least one lateral side of said article. By a complete penetration is herein understood a penetration wherein a large caliber projectile such as a 20 mm FSP enters the article through a side thereof, usually known as the impact side, and exits in its entirety the article through e.g. an opposite side thereof as can be verified with or without the use of a witness plate, e.g. and aluminum witness plate, facing said opposite side. Alternatively a complete penetration can be verified optically or with the help of a tracing wire carefully introduced to avoid piercing of the article through the penetration hole. In case the projectile shatters at impact with the article, a complete penetration is considered when shattered fragments, e.g. the largest of the shattered fragments, exit through said opposite side.

[0007] By a ballistic impact from a 20 mm FSP is herein understood the impact from said FSP traveling at velocities of at least 50 m/s. It was observed that the article of the invention does not only withstand repeated ballistic impacts from such large caliber projectiles but is also effective in withstanding multiple ballistic impacts from e.g. 20 mm FSP projectiles traveling at even higher velocities, e.g. velocities of at least 300 m/s.

[0008] The invention therefore also relates to a multi-ballistic-impact resistant article comprising a plurality of stacked monolayers, at least part of the monolayers containing at least one polyolefin tape, wherein said article is able to withstand at least three impacts without complete penetration from a 20 mm FSP traveling with a velocity of at least 50 m/s, more preferably of at least 100 m/s, even more preferably of at least 150 m/s, yet even more preferably of at least 200 m/s, yet more preferably of at least 250 m/s, most preferably of at least 300 m/s.

[0009] It was also surprising that the article of the invention is also effective against large caliber projectiles, e.g. 20 mm FSP, traveling at ultra-high velocities, e.g. a velocity of at least 450 m/s or even traveling with a velocity of at least 550 m/s. It was observed that the article of the invention is effective for large caliber projectiles, e.g. 20 mm FSP, traveling with a velocity of between 400 m/s and 800 m/s, more preferably between 450 m/s and 700 m/s, even more preferably

between 500 m/s and 650 m/s, most preferably between 500 m/s and 600 m/s.

[0010] Preferably, the article of the invention is able to withstand at least 4, more preferably at least 5, most preferably at least 6 impacts from a 20 mm FSP, which is preferably traveling with a velocity of at least 300 m/s, more preferably with a velocity between 550 and 650 m/s, most preferably between 550 m/s and 600 m/s.

[0011] It was observed that the article of the invention may have a reduced back face deformation (BFD). Preferably, the BFD of the article of the invention after multiple impacts from a 20 mm FSP traveling with a velocity of at least 300 m/s, more preferably with a velocity of between 550 m/s and 650 m/s, is at most 300 mm, more preferably at most 200 mm, most preferably at most 100 mm. The BFD of the article of the invention after multiple impacts from a 20 mm FSP it is referred hereinafter as the final BFD. It was observed that such final BFDs as obtained with the article of the invention for large caliber projectiles, e.g. 20 mm FSP, were never achieved hitherto for multi-hit articles comprising polyolefin containing monolayers.

[0012] It was surprisingly observed that the article of the invention has multi-hit resistance against large caliber projectiles, e.g. 20 mm FSP, even when said projectiles impact said article at a short distance from each other. It is well known that when projectiles repeatedly impact a ballistic article at multiple impact sites or locations, and when the distance between the impact sites is reduced, the multi-hit resistance of said article is reduced. The invention therefore relates to a multi-ballistic-impact resistant article comprising a plurality of stacked monolayers, at least part of the monolayers containing at least one polyolefin tape, said article having a strike face and a back face, wherein said article is able to withstand at least three impacts from a 20 mm FSP preferably traveling with a velocity of at least 300 m/s, without complete penetration, wherein the impacts take place on different locations on said strike face of the article and wherein at least two out of the three impact sites are at a distance of at most 500 mm. It was observed that the article of the invention withstands at least three impacts from a 20 mm FSP even when said distance between at least two out the three the impact sites is at most 350 mm and even at most 300 mm. It was also observed that the article of the invention is multi-hit resistant even when the distance between a first pair of impact sites is at most 350 mm and even at most 300 mm and wherein the distance between a second pair of impact sites is at most 150 mm and even at most 100 mm.

[0013] The distance between impact sites is herein understood to be the distance between the centers of the impacts and can be simply measured with a ruler.

[0014] It was further observed that the article of the invention has multi-hit resistance even when the large caliber projectiles impact said article under an angle of about 90°. This is surprising since at such impact angles the known lightweight ballistic articles suffer a complete destruction, i.e. complete penetration, even after a single impact from a large caliber projectile.

[0015] Most surprisingly, it was observed that the above-mentioned advantageous properties of the article of the invention, were achieved with a non-ceramic article. Therefore, preferably the article of the invention is a non-ceramic article. By a non-ceramic article is herein understood an article having a strike face and a back face, wherein the strike face is a non-ceramic strike face. Although called non-ceramic, by non-ceramic is herein understood a strike face substantially free of an inorganic material, e.g. metal such as steel, glass or ceramic. Such inorganic materials are usually used in enhancing the ballistic properties of known articles and may be utilized in any form, e.g. fibers, plates, platelets, plaques, panels and the like. It was also observed that the article of the invention is multi-hit resistant even if said article is substantially free of inorganic materials, i.e. all components such as strike face, back face and anything in between the strike face and the back face of said article are substantially free of inorganic materials. Therefore, in a preferred embodiment, the article of the invention is manufactured out of materials consisting of organic or synthetic matter.

[0016] Preferably, the article of the invention is a rigid article. By a rigid article is herein understood an article having a flexural strength of at least 10 MPa, more preferably of at least 20 MPa, most preferably of at least 40 MPa as measured before impacts. Flexural strength may be a measure of the rigidness of the article of the invention. It was observed that the article of the invention retains its rigidity to a large extent even after having been multiply impacted by large caliber projectiles. The article of the invention has preferably a residual flexural strength, i.e. the flexural strength of said article after the impacts, with at most 25% lower than its flexural strength before impacts, more preferably with at most 15% lower, most preferably with at most 10% lower, after having been impacted at least three times by 20 mm FSP projectile traveling at a speed of preferably at least 300 m/s, more preferably of between 500 and 600 m/s.

[0017] The article of the invention comprises a plurality of stacked monolayers, i.e. multiple monolayers stacked upon each other. By plurality of monolayers is herein understood monolayers in a number chosen to yield a total areal density of said plurality of monolayers of preferably at least 10 Kg/m^2, more preferably of at least 15 Kg/m^2, most preferably of at least 20 Kg/m^2. Preferably said total areal density is at most 180 Kg/m^2, more preferably at most 160 Kg/m^2, even more preferably at most 140 Kg/m^2, yet even more preferably at most 120 Kg/m^2, yet even more preferably at most 100 Kg/m^2, yet even more preferably at most 80 Kg/m^2, most preferably at most 60 Kg/m^2. Preferably, the total areal density of said plurality of monolayers is between 10 and 50 Kg/m^2, more preferably between 20 and 40 Kg/m^2, most preferably between 25 and 30 Kg/m^2. By total areal density of a plurality of monolayers is herein understood the sum of the individual areal densities of the monolayers forming said plurality of monolayers.

[0018] At least part of the monolayers contained by the article of the invention comprises at least one polyolefin tape.

Preferably at least 50% of all the monolayers used in the article of the invention comprise at least one polyolefin tape, more preferably at least 75%, most preferably substantially all said monolayers comprise at least one polyolefin tape. Preferably at least 50% of all the monolayers used in the article of the invention comprise at least one polyethylene tape, more preferably at least 75%, most preferably substantially all said monolayers comprise at least one polyethylene tape. It was observed that by increasing the number of monolayers comprising at least one polyolefin, and in particular polyethylene, tape in the article of the invention, the multi-hit properties of said article are improved.

[0019] By tape is herein understood an elongated body having a length dimension, a width dimension and a thickness dimension, wherein the length dimension of the tape is at least about the same as its width dimension but preferably greater than its width dimension, and wherein said length dimension is much greater than its thickness dimension. Preferably, the term tape also comprises the embodiments of a fiber, a monofilament, a multifilament, a ribbon, a strip, a film and may have a continuous or a discontinuous length with a regular or an irregular cross-section. In one embodiment, the tape has a length much greater than its width and thickness and wherein the ratio of width to thickness is between 1 and 5, more preferably between 1 and 3, such tape being also called filament. In a preferred embodiment, the width dimension of the tape is much greater than its thickness dimension.

[0020] In a preferred embodiment, at least part of the monolayers contained by the article of the invention comprise a single tape having a length and a width about the same as the length and width of the article. Hereinafter, for the purpose of this embodiment such a tape is referred to as film. The dimensions of width and length of the film are thus dependant on the dimensions of the article of the invention, which in turn are dependant on its application. The skilled person can routinely determine the lateral dimensions of said film. Preferably said film is anisotropic. By anisotropic is meant in the context of the present invention that two mutually perpendicular directions can be defined in the plane of the film for which the modulus of elasticity in a first direction is at least 3 times higher than the modulus of elasticity in the direction perpendicular to it. Generally the first direction of an anisotropic film is in the art also referred to as machine direction or drawing direction (or as direction of orientation) having the highest mechanical properties. Very good results were obtained when the monolayers containing the film were stacked such that the directions of orientation, i.e. the machine directions, of the films in two adjacent monolayers is under an angle α of preferably between 45 and 135°, more preferably between 65 and 115° and most preferably between 80 and 100°. A method of preparing such anisotropic films is disclosed for example in WO2010/066819, which is incorporated herein by reference.

[0021] In a further preferred embodiment, at least part of the monolayers contained by the article of the invention comprises a plurality of tapes. More preferably all monolayers used in the article of the invention comprise a plurality of tapes. Preferably, the tapes forming said plurality of tapes have a width of between 20 mm and 200 mm, more preferably between 50 mm and 150 mm, most preferably between 80 mm and 120 mm. Said tapes preferably have a thickness of between 5 μm and 200 μm, more preferably between 7.5 μm and 100 μm, most preferably between 10 μm and 60 μm. Preferably, said tapes have a width (W) to thickness (T) ratio (W/T) of at most 4000, more preferably at most 3000, most preferably at most 2500. Preferably, said tapes have a W/T ratio of at least 10, more preferably at least 20, most preferably at least 30.

[0022] In a further preferred embodiment of the invention, at least part of the monolayers contained by the article of the invention, preferably all of said monolayers, comprise a plurality of tapes, wherein the plurality of tapes is woven to form a woven monolayer. Preferred woven structures are plain weaves, basket weaves, satin weaves and crow-foot weaves. Most preferred woven structure is a plain weave. Preferably, the thickness of the woven monolayer is between 1.5 times the thickness of a tape and 3 times the thickness of a tape, more preferably about 2 times the thickness of a tape.

[0023] In a yet further preferred embodiment of the invention, at least part of the monolayers contained by the article of the invention, preferably all of said monolayers, comprise a plurality of tapes, wherein, the tapes forming said plurality are unidirectionally aligned. Preferably, in a monolayer containing unidirectionally aligned polymeric tapes at least 70 mass% of the total mass of tapes in said monolayer, more preferably at least 90 mass%, most preferably about 100 mass%, run along a common direction. Preferably, the tape running direction in a monolayer is at an angle β to the tape running direction in an adjacent monolayer, whereby β is preferably between 5 and 90°, more preferably between 45 and 90° and most preferably between 75 and 90°.

[0024] The monolayers used in accordance with the invention may also comprise a binder. The purpose of the binder is to hold the tapes together and improve the handleability of the monolayer. Various binders may be used, examples thereof including thermosetting and thermoplastic binders. A wide variety of thermosetting materials are available, however, epoxy resins or polyester resins are most common. Thermoplastic binders may also be used. Suitable thermosetting and thermoplastic polymer matrix materials are enumerated in, for example, WO 91/12136 A1 (pages 15-21) included herein by reference. From the group of thermosetting polymers, vinyl esters, unsaturated polyesters, epoxides or phenol resins are preferred. From the group of thermoplastic polymers, polyurethanes, polyvinyls, polyacrylics, polybutylene-terephthalate (PBT), polyolefins or thermoplastic elastomeric block copolymers such as polyisopropene-polyethylene-butylene-polystyrene or polystyrene-polyisoprene-polystyrene block copolymers are preferred.

[0025] More preferred, however, is that the at least part of the monolayers containing at least one polyolefin tape and used in accordance with the invention, preferably all of said monolayers, are substantially free of any binder or matrix

material the purpose of which might be to hold the tapes in place and/or to promote adhesion between adjacent monolayers. Most preferred is that the article of the invention is substantially free of any such binder or matrix material. Such an article proved to have a good multi-hit resistance.

[0026] The at least one tape used in accordance with the invention is made of a polyolefin polymer. The preferred polyolefin polymers are homopolymers and copolymers of polyethylene and/or polypropylene. Good results were obtained when the polyolefin is polyethylene. Preferred polyethylene tapes are ultrahigh molecular weight polyethylene (UHMWPE) tapes. Polyethylene tapes may be manufactured by any technique known in the art, e.g. a solid-state, a melt spinning or a gel spinning process. If a melt spinning process is used, the polyethylene starting material used for manufacturing tapes preferably has a weight-average molecular weight between 20,000 and 600,000 g/mol, more preferably between 60,000 and 200,000g/mol. An example of a melt spinning process is disclosed in EP 1,350,868 incorporated herein by reference. If a gel spinning process is used to manufacture said tapes, preferably a UHMWPE is used with an intrinsic viscosity (IV) of preferably at least 3 dl/g, more preferably at least 4 dl/g, most preferably at least 5 dl/g. Preferably the IV is at most 40 dl/g, more preferably at most 25 dl/g, more preferably at most 15 dl/g. Preferably, the UHMWPE has less than 1 side chain per 100 C atoms, more preferably less than 1 side chain per 300 C atoms. Preferably the UHMWPE tapes are manufactured according to a gel spinning process as described in numerous publications, including EP 0205960 A, EP 0213208 A1, US 4413110, GB 2042414 A, GB-A-2051667, EP 0200547 B1, EP 0472114 B1, WO 01/73173 A1, EP 1,699,954 and in "Advanced Fibre Spinning Technology", Ed. T. Nakajima, Woodhead Publ. Ltd (1994), ISBN 185573 182 7. To produce wide tapes, the above processes may be routinely adapted by using spinning dyes having spinning slits instead of spinning holes.

[0027] In a preferred embodiment the tapes used in accordance to the invention, are made by a process comprising step a) feeding a polyolefin powder bed between a combination of endless belts and compression-moulding the polyolefin powder bed between pressuring means at a temperature below the melting point of the polyolefin powder; step b) conveying the resultant compression-moulded polyolefin between calendar rolls to form a tape; and step c) drawing the tape. Preferably, the polyolefin used in this embodiment is UHMWPE.

[0028] Drawing, preferably uniaxial drawing, of the produced tapes may be carried out by means known in the art. Such means comprise extrusion stretching and tensile stretching on suitable drawing units. To attain increased mechanical strength and stiffness, drawing may be carried out in multiple steps. In case of the preferred UHMWPE tapes, drawing is typically carried out uniaxially in a number of drawing steps. The first drawing step may for instance comprise drawing to a stretch factor of 3. By multiple drawing at increasing temperatures, stretch factors of about 50 and more may be reached, whereby the process is run under such conditions, that no melting of the tape occurs e.g. a temperature below the melting temperature of the tape. This results in the high strength tapes, whereby at least for tapes of UHMWPE, strengths of 1.5 GPa and more may be obtained.

[0029] The tensile strength of the polyolefin tapes used in accordance with the invention is preferably at least 0.5 GPa, more preferably at least 1 GPa, most preferably at least 1.5 GPa. The tensile modulus of said polyolefin tapes is preferably at least 30 GPa, more preferably at least 50 GPa, most preferably at least 110 GPa. Good results were obtained when the polyolefin tapes were UHMWPE tapes having a tensile strength of at least 1.3 GPa, more preferably at least 1.5 GPa and a tensile modulus of at least 100 GPa, more preferably of at least 105 GPa, most preferably at least 110 GPa.

[0030] The article of the invention has an upper surface, a lower surface and lateral sides and wherein a first fibrous wrap encircles at least a portion of said upper surface, said lower surface and at least one lateral side of said article. Preferably, a second fibrous wrap encircles said article, the second fibrous wrap encircling the first fibrous wrap in a direction transverse to the encircling direction of the first fibrous wrap.

[0031] The first fibrous wrap and preferably the second fibrous wrap encircle the article of the invention preferably at least one time each, more preferably at least two times each most preferably at least three times each.

[0032] In a more preferred embodiment, the article of the invention has a first lateral side, a second lateral side opposite to said first lateral side, a third lateral side adjacent to the first lateral side and a fourth lateral side opposite to said third lateral side. Said article also has an upper surface and a lower surface. According to this embodiment, a first fibrous wrap encircles at least a portion of, more preferably substantially all of, the upper and the lower surface and at least a portion of, more preferably substantially all of, the first and the second lateral sides of the article. The article of this embodiment also preferably comprises a second wrap which encircles at least a portion of, more preferably substantially all of, the upper and the lower surface and at least a portion of, more preferably substantially all of, the third and the fourth lateral sides of the article.

[0033] Good results are obtained when the fibrous wraps are tightly wrapped around the surfaces and the sides of the stack of monolayers as explained immediately hereinabove. By wrapped tightly is herein meant that the fibrous wraps are taut, they being wrapped in such a way that substantially no slacking of the wraps occur and preferably also no excess of material occurs at the lateral sides of said stack of monolayers.

[0034] Preferably, the first fibrous wrap and/or the second fibrous wrap are/is a woven fabric comprising the polyolefin tapes. Examples of woven fabrics comprising polyolefin tapes and of polyolefin tapes are given hereinabove. It was observed that an article of the invention containing such wraps may withstand even at least 5 impacts from 20 mm FSP

without penetration.

[0035] Preferably, the areal density of the first fibrous wrap represents at least 0.75 % of the total areal density of the article of the invention, more preferably of at least 1.25 %, most preferably of at least 1.5 %.Preferably, the areal density of the first fibrous wrap represents at most 20% of the total areal density of the article of the invention, more preferably of at most 15%, most preferably of at most 10%. Preferably, the areal density of the second fibrous wrap represents at least 0.75 % of the total areal density of the article of the invention, more preferably of at least 1.25 %, most preferably of at least 1.5 %. Preferably, the areal density of the second fibrous wrap represents at most 20% of the total areal density of the article of the invention, more preferably of at most 15%, most preferably of at most 10%. Preferably, the first and/or the second fibrous wrap have a beginning portion and an end portion, wherein said beginning and said end portions are flushed, i.e. the end portion finishes in line with where the beginning portion starts. In an alternative embodiment, said beginning and end portions overlap or are at a distance with each other. By beginning and end of a wrap is herein understood the longitudinal extremities of the wrap which one uses to measure the length of the wrap. It was observed that when the wraps have their ends flushed, the efficiency of the article of the invention containing such wraps in stopping multiple impacts from large caliber projectiles such as 20 mm FSP increases.

[0036] The invention further relates to a manufacturing process of the article of the invention.

[0037] The article of the invention is manufactured with a process comprising the steps of:

a. Providing a plurality of monolayers, said monolayers having an upper face and a lower face, at least part of said monolayers comprising at least one polyolefin tape;

b. Subjecting the upper and/or the lower face of at least a number of monolayers comprising at least one polyolefin tape to a flame treatment;

c. Stacking the monolayers in such a manner that in at least part of the stack, at least one of the two adjoining faces of adjacent monolayers comprising at least one polyolefin tape is flame treated; and

d. Compressing the stacked monolayers under a pressure of at least 50 bars at a temperature below the peak temperature of melting (Tm) of said polyolefin tape, said Tm being determined by DSC under restrained conditions, wherein said process comprises also a wrapping step during which the stack of monolayers is encircled before or after step d) in a first direction with the fibrous first wrap.

[0038] The invention is also explained with the help of Figure, which depicts how a monolayer is subjected to a flame treatment process.

[0039] Preferably, all monolayers comprising at least one polyolefin tape and contained in the stack of monolayers have at least one face flame treated. Preferably, throughout the entire stack of monolayers, at least one of the two adjoining faces of adjacent monolayers comprising at least one polyolefin tape is flame treated.

[0040] Preferably, each of the monolayers used at step a) of the process of the invention comprises at least one polyolefin tape, more preferably each of the monolayers used at said step a) comprises a plurality of tapes, most preferably a plurality of woven or unidirectionally aligned tapes.

[0041] Preferably, both said upper and lower faces of said monolayers are flame treated in accordance with step b) of the process of the invention.

[0042] In a preferred embodiment, the process of the invention comprises step a1) wherein at least two of the monolayers provided at step a) are laminated together to form a ply having an upper ply surface and a lower ply surface and the upper ply surface and/or lower ply surface are then flame treated according to step b) of the invention.

[0043] Hereinafter, the term ply and the term monolayer are used interchangeably. The monolayers are preferably laminated together at a lamination temperature of preferably between 100°C and 150°C, more preferably between 130°C and 145°C and using a lamination pressure sufficient enough to laminate the monolayers together, e.g. a lamination pressure of preferably at least 100 N/m^2, more preferably at least 500 N/m^2, more preferably at least 1000 N/m^2.

[0044] The skilled person knows what equipment to use for flame treating monolayers, e.g. a combustion gas burner or direct flame processor (e.g. Flynn Burner's Flynn F3000). When such equipment is used, preferably the combustion gas is an oxygen rich (relative to stoichiometry) mixture of hydrocarbon gas, e.g. propane.

[0045] Preferably, at least 50% of the entire surface area of a monolayer is flame treated, more preferably at last 75%, most preferably the entire surface are of the monolayer is flame treated.

[0046] To automate step b) of the process of the invention, the monolayers may be placed on a conveyor belt having a certain line speed, and conveyed under a burner having a nozzle whose tip is positioned at a certain distance above the conveyor belt, wherein the monolayers' face to be flame treated is positioned towards the flame.

[0047] The intensity of the flame treatment primarily depends on the flame temperature at the tip of the nozzle of the burner, said temperature being easily adjusted by adjusting the flow of the combustion; the distance between the tip of the nozzle and the surface of the monolayer to be flame-treated; and the time of treatment, said time being easily adjustable by varying the line speed of the conveyor belt.

[0048] Preferably, the flame temperature at the tip of the nozzle is between 1500°C and 1800°C, more preferably

between 1650°C and 1750°C. To achieve such flame temperatures, the burner may use a mixture of air and fuel gas, where the air is at a pressure of preferably between 100 kPa and 400 kPa, more preferably of between 130 kPa and 350 kPa and the fuel gas is at a pressure of preferably between 0.5 kPa and 3 kPa, more preferably between 1.5 kPa and 2 kPa. The fuel gas can be butane, propane, methane or coal gas. Preferably, the nozzle of the burner is a single of double row ribbon burners. Using multiple ribbon burners has the advantage that the surface of the monolayer is flame treated during a single pass of the monolayer under the flame. Alternatively, to flame treat a face of a monolayer, a single ribbon burner can be used to scan the surface of the monolayer over a flame treatment area. It was observed that good results were achieved when the flame was oxidizing, e.g. the flame had a blue color or at least contained areas having a blue color. Such an oxidizing flame may be obtained for example by using a mixture of air and methane and adjusting the pressure of air to achieve an about 15% excess over the pressure of methane. The skilled person can obtain the temperature, the oxidizing characteristics and the color of the flame by routine experimentation.

[0049] Preferably, the line speed of the conveyor belt, which determines primarily the flame-treatment time, is between 10 m/min and 80 m/min, more preferably between 20 m/min and 60 m/min, most preferably between 40 m/min and 50 m/min.

[0050] With reference to Figure, the distance (100) between the tip (109) of the nozzle (101) and the surface (102) of the monolayer (103) to be flame treated is preferably adjusted to achieve an increase in the temperature measured at a working level (104) which is substantially equivalent to the level (105) at which the surface of said monolayer is located, from the ambient temperature (e.g. about 22°C) to a temperature of preferably between 300°C and 600°C, more preferably between 400°C and 550°C, most preferably between 450°C and 500°C, over an interval of time of preferably between 4 seconds and 7 seconds, more preferably of between 4 seconds and 5 seconds. Said distance (100) can be routinely determined by adjusting it while measuring the temperature at said working level (104) with e.g. a thermocouple (106) held under the flame (107) at the working level (104) for the required time interval, e.g. between 4 second and 5 second. A suitable system to be used for measuring temperatures may include a thermocouple model KX IEC 60584-3 from Thermoelectric, NL having a (+) contact made from NiCr and a (-) contact made from NiAl, said thermocouple being connected to a Pico data logger Model TC-08 from Pico Technology Limited. If the required temperature for the flame treatment is not achieved in the set time interval, the distance (100) may be decreased. Alternatively, if a higher temperature is achieved in the set time interval, the distance (100) may be increased. After adjusting the distance (100) the flame treatment is effected by conveying the monolayer in the direction of the arrow (108) under the flame with the required speed.

[0051] At step d) of the process of the invention, preferably, the pressure is between 80 bar and 450 bar; more preferably between 100 bar and 450 bar; even more preferably between 150 bar and 450 bar.

[0052] According to the process of the invention, the stack of monolayers is compressed at a temperature (T) below the peak temperature of melting (Tm) of the polyolefin tape, the Tm being determined by DSC under restrained conditions. It was observed that the Tm of the polyolefin tape may increase when the tape is under restrained conditions, e.g. when the tape is subjected to a pressure as in step d) of the process of the invention. Preferably the temperature T satisfies the following conditions: Tm - 30°C < T < Tm; more preferably Tm - 20°C < T < Tm - 3°C; most preferably Tm - 10°C < T < Tm - 3°C. In the case when the polyolefin tape does not allow a precise determination with DSC of said peak temperature of melting (Tm), said Tm is considered the temperature at which the polyolefin tape breaks during a tensile measurement test when the tape is placed under a load equal to 2% of its normal tensile strength, said normal tensile strength being the strength measured with the tensile measurement test at room temperature (22°C).

[0053] Preferably, after step d) of the process of the invention is completed, the compressed stack of monolayers is cooled to room temperature while being kept under pressure, i.e. the pressure applied at said step d) is released only when the stack of monolayers is already cooled, e.g. to room temperature.

[0054] The process of the invention also comprises a wrapping step carried out before or after step d) of the process of the invention. During the wrapping step, the stack of monolayers is encircled before or after compression in a first direction with a first wrap having a length preferably adapted to achieve at least one first wrapping, more preferably at least two, most preferably at least three first wrappings of said stack of monolayer. Preferably a second wrap is used in a second direction substantially perpendicular to the first direction to achieve at least one second wrapping, more preferably at least two, most preferably at least three second wrappings of said stack of monolayers.

[0055] Preferably the fibrous wraps tightly encircle the stack of monolayers to prevent excess of material coming from fibrous wraps slacking at the lateral sides and/or at the surfaces of the stack of monolayers.

[0056] When the wrapping step is carried out after step d) of the process of the invention, preferably said process comprises an additional compressing step e) preferably carried out under the same temperature and pressure conditions as for step d) of the process of the invention.

[0057] It was observed than when the wrapping step is present, the flame treatment step b) in the process of the invention may be dispensed with. However, preferably the process of the invention comprises both the flame treatment step b) and the wrapping step wherein preferably, the first and/or second wraps are flame treated as well in accordance with step b) of the invention.

[0058] The invention also relates to various products comprising the article of the invention, said product being chosen from the group consisting of an armor, a vehicle, a building or a building component. Examples of vehicles include automobiles, motorcycles, buses, trains, planes, helicopters, jets, trucks, boats, satellites and space exploration vehicles, but also already armored vehicles, in particular light armored vehicles. Examples of building components include pillars, walls, windows and doors.

[0059] The invention will be further explained with the help of the following examples and comparative experiments without being limited however thereto.

METHODS OF MEASURING

[0060]

- Flexural strength of an article is measured according to ASTM D790-07. To adapt for various thicknesses of the article, measurements are performed according to paragraph 7.3 of ASTM D790-07 by adopting a loading and a support nose radius which are twice the thickness of the article and a span-to-depth ratio of 32.
- Areal density (AD) was determined by measuring the weight of a sample of preferably 0.4 m $\times$ 0.4 m with an error of 0.1 g.
- Intrinsic Viscosity (IV) for polyethylene is determined according to method PTC-179 (Hercules Inc. Rev. Apr. 29, 1982) at 135°C in decalin, the dissolution time being 16 hours, with DBPC as anti-oxidant in an amount of 2 g/l solution, by extrapolating the viscosity as measured at different concentrations to zero concentration.
- Side chains in a polyethylene or UHMWPE sample is determined by FTIR on a 2 mm thick compression molded film by quantifying the absorption at 1375 cm-1 using a calibration curve based on NMR measurements (as in e.g. EP 0 269 151)
- Tensile properties, i.e. strength and modulus, of fibers were determined on multifilament yarns as specified in ASTM D885M, using a nominal gauge length of the fibre of 500 mm, a crosshead speed of 50%/min and Instron 2714 clamps, of type Fibre Grip D5618C. For calculation of the strength, the tensile forces measured are divided by the titre, as determined by weighing 10 metres of fibre; values in GPa for are calculated assuming the natural density of the polymer, e.g. for UHMWPE is 0.97 g/cm3.
- The tensile properties of tapes and films: tensile strength and tensile modulus are defined and determined at 25 °C on tapes (if applicable obtained by slitting films) of a width of 2 mm as specified in ASTM D882, using a nominal gauge length of the tape of 440 mm, a crosshead speed of 50 mm/min.
- The melting temperature (also referred to as melting point) of a polyolefin tape is determined by DSC on a power-compensation PerkinElmer DSC-7 instrument which is calibrated with indium and tin with a heating rate of 10°C/min. For calibration (two point temperature calibration) of the DSC-7 instrument about 5 mg of indium and about 5 mg of tin are used, both weighed in at least two decimal places. Indium is used for both temperature and heat flow calibration; tin is used for temperature calibration only. The tapes were hand-winded around a support to simulate restrained conditions.
- Tensile modulus of binders and matrix materials was measured according to ASTM D-638(84) at 25°C.
- Back face deformation was tested according to NIJ 0101.04 level IIIA using 20 mm FSP on an internal shooting template.
- Ballistic performance was measured by subjecting the armor to shooting tests performed with standard (STANAG) 20 mm FSP. The first shot was fired at a projectile speed (V50) at which it is anticipated that 50% of the shots would be stopped. The actual bullet speed was measured at a short distance before impact. If a stop was obtained, the next shot was fired at an anticipated speed being 10% higher than the previous speed. If a perforation occurred, the next shot was fired at a speed 10% lower than the previous speed. The result for the experimentally obtained V50 value was the average of the two highest stops and the two lowest perforations. The kinetic energy of the bullet at V50 was divided by the total areal density of the armor to obtain a so-called Eabs value. Eabs reflects the stopping power of the armor relative to its weight/thickness thereof. The higher the Eabs the better the armor is.
- The speed of the projectile was measured with a pair of Drello Infrared (IR) light screen Type LS19i3 positioned perpendicular on the path of the projectile. At the instant when a projectile passes through the first light screen a first electric pulse will be produced due to the disturbance of the IR beam. A second electric pulse will be produced when the projectile passes through the second light screen. Recording the moments in time when the first and the second electric pulses occur, and knowing the distance between the light screed the speed of the projectile can be immediately determined.

EXAMPLES AND COMPARATIVE EXPERIMENT

Comparative Example 1

[0061] A number of 300 rectangular monolayers were utilized to create an anti-ballistic article, said monolayers containing a plain woven fabric made of UHMWPE tapes. The tapes had a tensile strength of 1.7 GPa, a tensile modulus of 115 GPa, a width of about 100 mm, and a thickness of about 45 μm. A total number of 10 tapes were used to create a plain woven monolayer from which 5 tapes were used as warp tapes and 5 tapes were used as waft tapes. The lateral sizes, i.e. width and length of the monolayers were both 500 mm. Pairs of two monolayers were laminated to form a ply.

[0062] Both upper and lower surfaces of the plies were flame treated in their entirety by conveying the plies with a speed of about 40 m/min under a blue flame obtained from a burner (PZ5000 from CFH-gmbh, DE). The flame had a temperature at the nozzle of about 1750°C and at its tip of about 730°C. The burner was used at a gas flow of about 0.027 g/sec. The distance (100) between the surface (102) of the monolayer (103) and the tip of the nozzle (101) was adjusted to achieve a temperature increase at the surface of the monolayer from the ambient temperature (about 22°C) to 450°C in a time interval of about 5 seconds.

The monolayers were stacked upon each other and than pressed under a pressure of 165 bars at a temperature of 130 °C for 65 min. After the pressing cycle was completed, the obtained compressed article was cooled under pressure to room temperature. The flexural strength of the compressed article was about 50 MPa. The obtained compressed article was subjected to a shooting test with 20 mm FSP at different speeds. The results are presented in Table.

Example

[0063] Comparative Example 1 was repeated with the difference that after being compressed, the stack of monolayers was encircled three times with a first fabric wrap and than three times with a second fabric wrap. The second fabric wrap encircled the first fabric wrap in a direction transverse to the encircling direction of the first fibrous wrap. The ends of the wraps were flushed. The wraps were flame treated in accordance with the methodology explained in Comparative Example 1. The fabric wraps were fabrics woven in a plain weave construction from the UHMWPE tapes of Comparative Example 1. To achieve an article having the same areal density as the article of Comparative Example 1, 24 monolayers were removed from the stack prior to pressing, yielding a total number of monolayers of 276. The obtained compressed article was then subjected to the wrapping step and the wrapped article compressed again under the same conditions as in Example 1 but only for 10 minutes. The flexural strength of the compressed article was about 50 MPa.

[0064] A shooting test with 20 mm FSP at different speeds was carried out. The results are presented in Table.

Comparative Example 2

[0065] The Example was repeated with the difference that no flame treatment took place. The results are presented in Table.

Comparative Example 3

[0066] Comparative Example 1 was repeated with the difference that the monolayers were not flame treated. The obtained compressed article was subjected to a shooting test with 20 mm FSP. The results are presented in Table.

[0067] From Table can be observed that in comparison with known articles, the article of the invention can withstand at least one more impact from a high velocity 20 mm FSP. In most circumstances, this may mean the difference between life and death.

Table

	Total AD (Kg/m^2)	20 mm FSP shooting speed (m/s)	Distance between impacts (mm)	Number of stops without complete penetration	Final BFD (mm)
Comparative Example 1	25	550	80	3	250
		551	80	3	250
Example	25	550	200	4	100
		553	200	4	100
		550	200	5	120

(continued)

	Total AD (Kg/m^2)	20 mm FSP shooting speed (m/s)	Distance between impacts (mm)	Number of stops without complete penetration	Final BFD (mm)
Comparative Example 2	25	551	150	4	300
Comparative Example 3	25	550	100	2	350

Claims

1. A multiple-ballistic-impact resistant article having an upper surface, a lower surface and lateral sides, said article comprising a plurality of stacked monolayers and at least part of the monolayers containing at least one polyolefin tape, said plurality of stacked monolayers has a total areal density of less than 200 Kg/m^2, wherein the upper and/or lower face of at least a number of monolayers comprising at least one polyolefin tape have been subjected to a flame treatment, and wherein a first fibrous wrap encircles at least a portion of said upper surface, said lower surface and at least one lateral side of said article.

2. The article according to claim 1 wherein a second fibrous wrap encircles said article, and the second fibrous wrap encircles the first fibrous wrap in a direction transverse to the encircling direction of the first fibrous wrap.

3. The article according to any one of the preceding claims, wherein the fibrous wraps are a woven fabric comprising polyolefin tapes.

4. The article according to any one of the preceding claims, wherein the first fibrous wrap encircles the article at least one time.

5. The article according to any one of claims 2-4, wherein the second fibrous wrap encircles the article at least one time.

6. The article according to any one of the preceding claims, wherein the fibrous wraps are tightly wrapped around the surfaces and the sides of the stack of monolayers

7. The article according to any one of the preceding claims, wherein the areal density of the first fibrous wrap represents at least 0.75% and at most 20% of the total areal density of the article.

8. The article according to any one of the preceding claims wherein the plurality of stacked monolayers has a total areal density in between 10 to 50 Kg/m^2.

9. The article according to any one of the preceding claims wherein the monolayers are unidirectional monolayers.

10. The article according to any one of the preceding claims wherein the polyolefin tape is an ultrahigh molecular weight polyethylene (UHMWPE) tape.

11. The article according to any one of the preceding claims wherein said article has a flexural strength of at least 10 MPa as measured before impact.

12. A process for manufacturing an article according to any one of the preceding claims, comprising the steps of:

    a. providing a plurality of monolayers, said monolayers having an upper face and a lower face, at least part of said monolayers comprising at least one polyolefin tape;
    b. subjecting the upper and/or lower face of at least a number of monolayers comprising at least one polyolefin tape to a flame treatment;
    c. stacking the monolayers in such a manner that in at least part of the stack, at least one of the two adjoining faces of adjacent monolayers comprising at least one polyolefin tape is flame treated; and
    d. compressing the stacked monolayers under a pressure of at least 50 bars at a temperature below the peak

temperature of melting (T_m) of said polyolefin tape, said T_m being determined by DSC under restrained conditions, wherein said process comprises also a wrapping step during which the stack of monolayers is encircled before or after step d) in a first direction with a fibrous first wrap.

13. Process according to claim 12, wherein in step a) a fibrous second wrap is provided and used in the wrapping step in a second direction substantially perpendicular to the first direction.

14. Process according to any one of claims 12-13, wherein prior to step b) the upper and/or the lower face of at least a number of monolayers comprising at least one polyolefin tape are been subjected to a flame treatment.

15. An armor, a vehicle, a building or a building component comprising an article according to any one of claims 1-14.

Patentansprüche

1. Mehrfachballistikschutzerzeugnis mit Oberseite, Unterseite und Seitenflächen, umfassend mehrere gestapelte Monoschichten, die wenigstens zum Teil mindestens ein Polyolefinband enthalten, wobei die mehreren gestapelten Monoschichten über eine Gesamtflächendichte von weniger als 200 kg/m^2 verfügen, wobei wenigstens eine Anzahl der mindestens ein Polyolefinband umfassenden Monoschichten an der Ober- und/oder Unterseite flammend behandelt worden sind und wobei das Erzeugnis oberseitig, unterseitig und mindestens einfach seitenflächig wenigstens teilflächig mit einem ersten Faserwickel umwickelt ist.

2. Erzeugnis nach Anspruch 1, bei dem das Erzeugnis ferner mit einem zweiten Faserwickel umwickelt ist, der den ersten Faserwickel quer zu dessen Umwicklungsrichtung umwickelt.

3. Erzeugnis nach einem der vorhergehenden Ansprüche, bei dem als Faserwickel ein Polyolefinbänder umfassendes Gewebe dient.

4. Erzeugnis nach einem der vorhergehenden Ansprüche, bei dem das Erzeugnis mindestens einfach mit dem ersten Faserwickel umwickelt ist.

5. Erzeugnis nach einem der Ansprüche 2-4, bei dem das Erzeugnis mindestens einfach mit dem zweiten Faserwickel umwickelt ist.

6. Erzeugnis nach einem der vorhergehenden Ansprüche, bei dem der Stapel aus Monoschichten mit den Faserwickeln allseitig fest umwickelt ist.

7. Erzeugnis nach einem der vorhergehenden Ansprüche, bei dem bezogen auf dessen Gesamtflächendichte die Flächendichte des ersten Faserwickels einen Anteil von mindestens 0,75% und höchstens 20% darstellt.

8. Erzeugnis nach einem der vorhergehenden Ansprüche, bei dem die mehreren gestapelten Monoschichten über eine Gesamtflächendichte zwischen 10 bis 50 kg/m^2 verfügen.

9. Erzeugnis nach einem der vorhergehenden Ansprüche, bei dem es sich um unidirektionale Monoschichten handelt.

10. Erzeugnis nach einem der vorhergehenden Ansprüche, bei dem als Polyolefinband ein solches aus ultrahochmolekularem Polyethylen (UHMWPE) dient.

11. Erzeugnis nach einem der vorhergehenden Ansprüche mit einer bevor Aufschlag gemessenen Biegefestigkeit von mindestens 10 MPa.

12. Verfahren zur Herstellung eines Erzeugnisses gemäß einem der vorhergehenden Ansprüche, umfassend die Schritte:

a. Bereitstellung mehrerer Monoschichten mit Oberseite und Unterseite, die wenigstens zum Teil mindestens ein Polyolefinband umfassen,
b. flammende Behandlung der Ober- und/oder Unterseite wenigstens einer Anzahl der mindestens ein Polyolefinband umfassenden Monoschichten,

c. Stapelung der Monoschichten, derart, dass in wenigstens einem Teil des Stapels mindestens eine der beiden aneinandergrenzenden Flächen der mindestens ein Polyolefinband umfassenden benachbarten Monoschichten flammend behandelt wurde und

d. Verpressung der gestapelten Monoschichten unter einem Druck von mindestens 50 bar bei einer Temperatur unterhalb der Spitzentemperatur beim Schmelzen (T_m) des Polyolefinbands, wobei man T_m mittels DSC im gestreckten Zustand bestimmt, wobei das Verfahren auch einen Wickelschritt umfasst, bei dem der Stapel aus Monoschichten vor oder nach Schritt d) mit einem ersten Faserwickel in einer ersten Richtung umwickelt wird.

13. Verfahren nach Anspruch 12, bei dem in Schritt a) ein zweiter Faserwickel bereitgestellt und im Wickelschritt in einer zweiten Richtung angewendet wird, die gegenüber der ersten Richtung weitgehend senkrecht verläuft.

14. Verfahren nach einem der Ansprüche 12-13, bei dem wenigstens eine Anzahl der mindestens ein Polyolefinband umfassenden Monoschichten vor Schritt b) ober- und/oder unterseitig flammend behandelt werden.

15. Panzerplatte, Fahrzeug, Gebäude oder Gebäudeteil mit Erzeugnis gemäß einem der Ansprüche 1-14.

Revendications

1. Article résistant à un impact balistique multiple comprenant une surface supérieure, une surface inférieure et des côtés latéraux, ledit article comprenant une pluralité de monocouches superposées et au moins une partie des monocouches contenant au moins un ruban en polyoléfine, ladite pluralité de monocouches superposées ayant une masse surfacique totale inférieure à 200 kg/m^2, dans lequel la face supérieure et/ou la face inférieure d'au moins plusieurs monocouches comprenant au moins un ruban en polyoléfine a/ont été soumise(s) à un traitement par flamme, et dans lequel un premier matériau d'enveloppement fibreux est enroulé autour d'au moins une partie de ladite surface supérieure, de ladite surface inférieure et d'au moins un côté latéral dudit article.

2. Article selon la revendication 1, dans lequel un deuxième matériau d'enveloppement fibreux est enroulé autour dudit article, et le deuxième matériau d'enveloppement fibreux est enroulé autour du premier matériau d'enveloppement fibreux dans une direction transversale à la direction d'enroulement du premier matériau d'enveloppement fibreux.

3. Article selon l'une quelconque des revendications précédentes, dans lequel les matériaux d'enveloppement fibreux sont constitués d'un tissu tissé comprenant des rubans en polyoléfine.

4. Article selon l'une quelconque des revendications précédentes, dans lequel le premier matériau d'enveloppement fibreux est enroulé au moins une fois autour de l'article.

5. Article selon l'une quelconque des revendications 2 à 4, dans lequel le deuxième matériau d'enveloppement fibreux est enroulé au moins une fois autour de l'article.

6. Article selon l'une quelconque des revendications précédentes, dans lequel les matériaux d'enveloppement fibreux sont enroulés serrés autour des surfaces et des côtés de la superposition de monocouches.

7. Article selon l'une quelconque des revendications précédentes, dans lequel la masse surfacique du premier matériau d'enveloppement fibreux représente au moins 0,75 % et au maximum 20 % de la masse surfacique totale de l'article.

8. Article selon l'une quelconque des revendications précédentes, dans lequel la pluralité de monocouches superposées a une masse surfacique totale de 10 à 50 kg/m^2.

9. Article selon l'une quelconque des revendications précédentes, dans lequel les monocouches sont des monocouches unidirectionnelles.

10. Article selon l'une quelconque des revendications précédentes, dans lequel le ruban en polyoléfine est un ruban en polyéthylène à ultra-haute masse moléculaire (UHMWPE).

11. Article selon l'une quelconque des revendications précédentes, ledit article ayant une résistance à la flexion d'au moins 10 MPa, mesurée avant l'impact.

12. Procédé de fabrication d'un article selon l'une quelconque des revendications précédentes, comprenant les étapes qui consistent à :

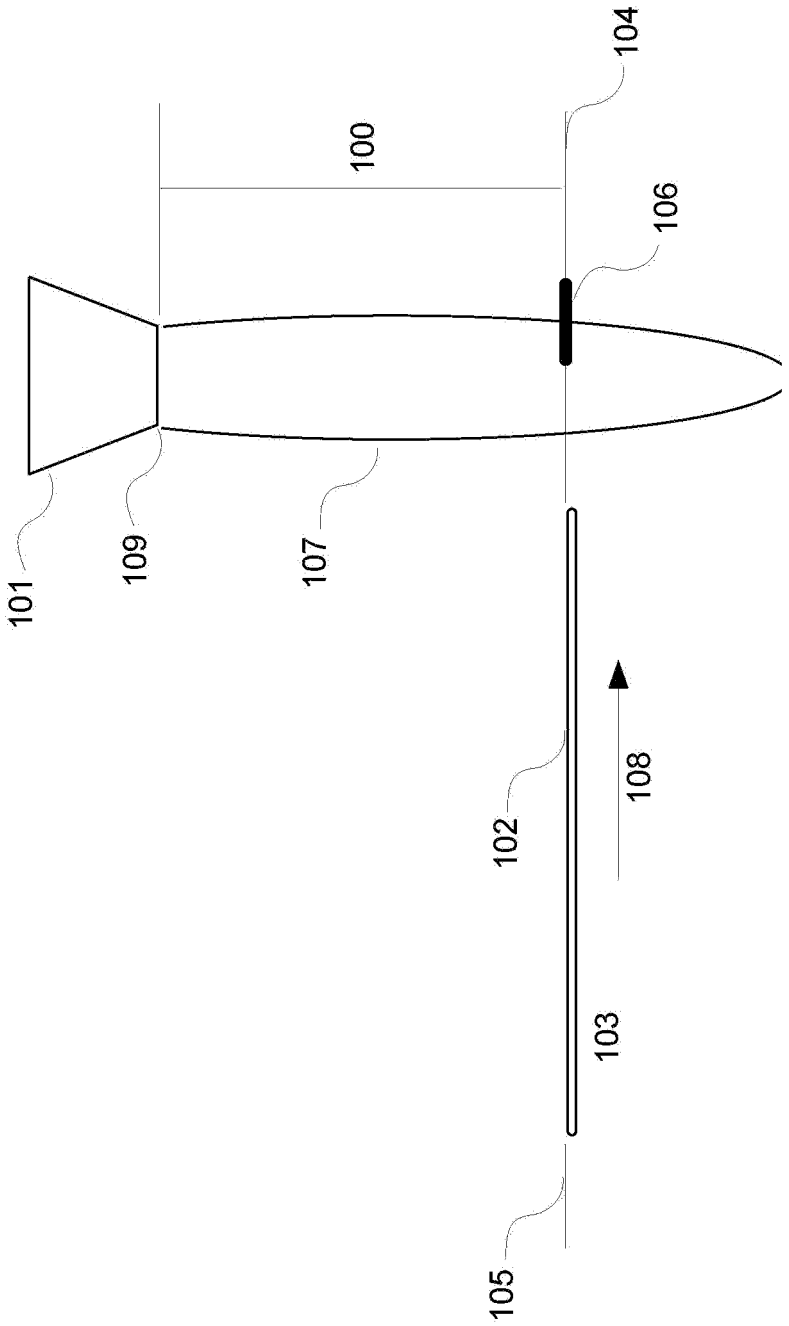
a. fournir une pluralité de monocouches, lesdites monocouches ayant une surface supérieure et une surface inférieure, au moins une partie desdites monocouches comprenant au moins un ruban en polyoléfine ;
b. le fait de soumettre la face supérieure et/ou la face inférieure d'au moins plusieurs monocouches comprenant au moins un ruban en polyoléfine à un traitement par flamme ;
c. le fait de superposer les monocouches de telle sorte que dans au moins une partie de la superposition, au moins une des deux faces disposées de façon contiguë de monocouches adjacentes comprenant au moins un ruban en polyoléfine ait subi un traitement par flamme ; et
d. la compression des monocouches superposées sous une pression d'au moins 50 bars à une température inférieure à la température de fusion maximale (T_m) dudit ruban en polyoléfine, ladite T_m étant déterminée par calorimétrie différentielle à balayage sous des conditions d'immobilisation,
ledit procédé comprenant aussi une étape d'enveloppement durant laquelle un premier matériau d'enveloppement fibreux est enroulé autour de la superposition de monocouches avant ou après l'étape d) dans une première direction.

13. Procédé selon la revendication 12, dans lequel à l'étape a) un deuxième matériau d'enveloppement fibreux est fourni et utilisé dans l'étape d'enveloppement dans une deuxième direction sensiblement perpendiculaire à la première direction.

14. Procédé selon l'une quelconque des revendications 12 ou 13, dans lequel avant l'étape b) la face supérieure et/ou la face inférieure d'au moins plusieurs monocouches comprenant au moins un ruban en polyoléfine est/sont soumise(s) à un traitement par flamme.

15. Article blindé, véhicule, bâtiment ou élément d'un bâtiment comprenant un article selon l'une quelconque des revendications 1 à 14.

Figure



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