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(54) Title: ANTIBALLISTIC PANEL

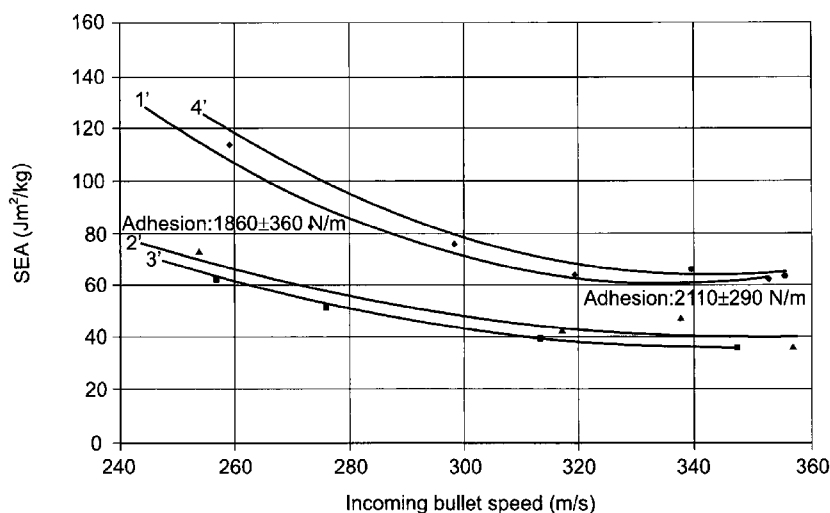


Fig. 2

(57) Abstract: The invention pertains to an antiballistic panel comprising at least a first stack and a second stack, wherein the first stack has a plurality of first laminates made of a first kind of yarn and the second stack has a plurality of second laminates made of a second kind of yarn, wherein the first kind of yarn has linear density of at least 1001 dtex measured by ASTM D1907 and a filament linear density of at most 1.2 dtex measured by ASTM D1577-07, option C-2 and the second kind of yarn has a linear density of at most 1000 dtex measured by ASTM D1907 and a filament linear density of at least 1.3 dtex measured by ASTM D1577-07 option C-2.

Antiballistic panel

Description:

The invention pertains to an antiballistic panel comprising at least a first kind of stack and a second kind of stack.

Antiballistic panels are well known in the related art.

For example, a ballistic resistance panel is disclosed in WO 2008/14020. The panel according to this document comprises a first fiber layer and a second fiber layer, wherein the first and the second fiber layer have different types of high tenacity fibers. The first and the second fiber layer are formed of a plurality of plies, which have been laminated together.

The article of US 2005/0003727 combines spike and ballistic resistant panels. The fabrics of the spike resistant panel are made from yarns with a linear density of 55 to 660 dtex and a filament linear density in the range of 0.33 to 8.9 dtex. The fabrics of the ballistic resistant panel are made from yarns with a linear density from 110 to 930 dtex and a filament linear density in the range of 0.33 to 8.9 dtex.

DE 37 43 243 discloses a laminate of at least two layers, at least one of these layers being a textile fabric of aramid yarns and at least one polymer film. The yarns have a linear density of at least 420 dtex, preferably 1610 to 8050 dtex and the filaments have a linear density of 0.8 to 1.2 dtex.

In document WO 2008/115913 a multilayer composite fabric is disclosed. Also this composite fabric comprises a first and a second layer with high tenacity fibers, wherein the layers are directly or indirectly bonded together.

Document US 2005/0153098 discloses a hybrid-laminated sheet. The sheet comprises laminates, wherein each laminate comprises different layers. A first and a fourth layer is made of a first kind of fiber and a second and third layer is made of a second, different kind of fiber.

In the prior art documents the different fiber types are used in combination with each other. This means, different fiber types are combined in one layer with each other or layers of different fiber types make a laminate. In such a combination the positive effect of a special kind of fiber is overlapped by the other kind of fiber.

It is therefore the aim of the present invention to create an antiballistic panel in which the properties of different fiber types are positively influenced by the other fiber type.

The aim is achieved by an antiballistic panel with the features of claim 1.

The antiballistic panel according to claim 1 comprises at least a first kind of stack (first stack) and a second kind of stack (second stack), wherein the first kind of stack has a plurality of first laminates made of a first kind of yarn and the second kind of stack has a plurality of second laminates made of a second kind of yarn, wherein the first kind of yarn has a linear density of at least 1001 dtex measured by ASTM D1907 and a filament linear density of at most 1.2 dtex measured by ASTM D1577-07, option C-2 and calculated by dividing the yarn linear density by the number of filaments and the second kind of yarn has a linear density of at most

1000 dtex measured by ASTM D1907 and a filament linear density of at least 1.3 dtex measured by ASTM D1577-07, option C-2.

Due to the fact that the first stack exhibits as yarn only the first kind of yarn and the second stack exhibits as yarn only the second kind of yarn the properties of these different kinds of yarn fibers still remain. It has shown that a panel comprising two different kind of stacks made of yarn of different fibers has a better antiballistic performance than a panel comprising two stacks, wherein each stack consists of both types of different fibers. For a person skilled in the art this result was absolutely surprisingly.

The term linear density should be understood as a measure of mass per unit of length, and it is a characteristic of strings or other one-dimensional objects. The most commonly used unit is actually the decitex, abbreviated dtex, which is the mass in grams per 10,000 meters.

For the purposes of the present invention, a yarn comprises fibers and/or filaments, whereby a fiber is an elongate body the length dimension of which is much greater than the transverse dimensions of width and thickness. A fiber comprises at least one filament. Accordingly, the term fiber includes monofilament, multifilament, ribbon, strip, staple and other forms of chopped, cut or discontinuous fiber or filaments and the like having regular or irregular cross-section.

A laminate should be understood as a combination of at least two yarn layers (or also called fiber layers) with a matrix material. Preferably, every fiber layer is impregnated with a matrix material, most preferred with the same matrix material. If different matrix materials are used the matrix materials distinguished from each other. As a first matrix material an elastomer for example can be used. As second matrix material an epoxy resin can be used. In another preferred embodiment the

matrix materials in different fiber layers is the same or different and different fiber layers have different matrix contents. In an especially preferred embodiment a laminate has on two outer surfaces a film. Preferably, a laminate comprises four fiber layers, whereby each fiber layer is impregnated with a matrix material.

A yarn layer can be synonymous called as a fiber layer. Preferably, a fiber layer is a unidirectional fiber layer or a woven fiber layer. Both mentioned layers could be impregnated with a matrix material. A stack can exhibit only unidirectional fiber layers or woven fiber layers or a combination of both kinds of layers.

The first stack as well as the second stack comprises a plurality of laminates. Each of the laminates preferably comprises at least two fiber layers. The first stack exhibits laminates made of a first kind of fibers. Preferably, no other fibers are used for the laminates and therefore for the first stack. The second stack exhibits also a plurality of laminates, but the laminates of the second stack are made of a second kind of fibers. Preferably, no other fibers (or yarn) are used for the laminates in the second stack. Due to this the first stack and the second stack are made of different fibers (or yarns), wherein the fibers distinguished in respect to the used linear density and filament linear density.

In a preferred embodiment at least one layer of the first stack and/or second stack is made of tapes. This means at least one laminate of the first stack and/or second stack comprises (among at least one yarn layer) at least one layer made of tape.

Preferably, each of the plurality of laminates of the first and/or the second stack comprises at least one unidirectional fiber layer, more preferred each laminate comprises at least two unidirectional fiber layers and most preferred four unidirectional fiber layers. Preferably, the fibers of the yarn of the unidirectional

layers are in a matrix. The fiber direction of a layer in a laminate has an angle relative to the fiber direction of an adjacent layer of the same laminate, wherein the angle is preferably between 40° and 100°, more preferred between 45° and 95° and most preferred 90°.

Unidirectional fiber layers are built up by fibers of yarn, which are aligned parallel to each other along a common fiber direction. In a preferred embodiment at least one layer of the laminate comprises unidirectional aligned tapes. The resin matrix material for the layers may be formed from a wide variety of elastomeric materials having desired characteristics. In one embodiment, the elastomeric materials used in such matrix possess an initial tensile modulus (modulus of elasticity) equal to or less than about 6,000 psi (41.4 MPa) as measured according to ASTM D638.

More preferably, the elastomer has an initial tensile modulus equal to or less than about 2,400 psi (16.5 MPa). Most preferably, the elastomeric material has an initial tensile modulus equal to or less than about 1,200 psi (8.23 MPa). These resin materials are typically thermoplastic in nature but thermosetting materials are also useful. The proportion of the resin material to fiber in the layer may vary widely depending upon the end use and is usually in the range of 5-26% based on matrix weight in respect to matrix and fiber weight. Suitable matrix materials are SIS (styrene-isoprene-styrene) block copolymers, SBR (styrene butadiene rubber), polyurethanes, ethylene acrylic acid, polyvinyl butyral.

Preferably, at least one laminate of first and/or the second stack comprises at least a woven fiber layer.

Preferably, the number of laminates, which builds up a first and/or second stack is between 1 to 30. This means the first and/or second stack have between 2 and 120 layers.

Preferably, the panel has a body face and a strike face, whereby the first stack is arranged to the strike face and the second stack is arranged to the body face of the panel. The body face is arranged to the body of the wearer. In another preferred embodiment is the first stack arranged to the body face and the second stack is arranged to the strike face.

Suitable fibers for the layers of the first stack may be aramid fibers, like Twaron® Type 2000, 1100 dtex, 1000 filaments, Twaron® Type D2600, 1100 dtex, 2000 filaments (development product).

Suitable fibers for the layers of the second stack may also be aramid fibers, like Twaron® Type 2000, 840dtex, 500 filaments.

Preferably, at least one laminate of the first and/or the second stack has at least one film on its outer surface. It is especially preferred, if a laminate has on each outer surface a film. This means each laminate of the first and/or second stack comprises preferably two films, whereby the films are arranged on the outer surfaces of the laminate. The films can be included on the layers, for example to permit different layers to slide over each other. The films may typically be adhered to one or both surfaces of each layer. Any suitable film may be employed, such as films made of polyolefin, e.g. linear low density polyethylene (LLDPE) films and ultrahigh molecular weight polyethylene (UHMWPE) films, as well as polyester films, nylon films, polycarbonate films and the like. These films may be of any desirable thickness. Typical film thickness ranges from about 2-20 μm .

Preferably, the panel is used for hard or soft anti-ballistic applications.

Preferably, the first stack comprising a plurality of unidirectional layers, whereby each layer is made of a 1100 dtex aramid yarn comprising 1.1 dtex filaments. The layers are impregnated with Rovene® 4019 (MCP, Mallard Creek Polymers) as matrix material. In this embodiment the second stack comprises a plurality of unidirectional layers, whereby each layer is made of a 840 dtex aramid yarn comprising 1.68 dtex filaments. The layers for the second stack are impregnated with a matrix mixture of approximately 60% Rovene® 4220 and approximately 40% of Rovene® 4176. The first stack or the second stack can be arranged on the strike face or the body face.

In another preferred embodiment the first stack comprises a plurality of unidirectional layers made of a 840 dtex aramid yarn comprising 1.68 dtex filaments. The layers are impregnated with Rovene® 4019 as matrix material. In this embodiment the second stack comprises a plurality of unidirectional layers, whereby each layer is made of a 1100 dtex aramid yarn comprising 1.1 dtex filaments. The layers for the second stack are impregnated with a matrix mixture of approximately 60% Rovene® 4220 and approximately 40% Rovene® 4176. The first stack or the second stack can be arranged on the strike face or the body face.

In another preferred embodiment the first stack comprises a plurality of unidirectional layers made of a 1100 dtex aramid yarn comprising 1.1 dtex filaments. The layers are impregnated with Rhoplex® E-358 (Rohm and Haas) as matrix material. In this embodiment the second stack comprises a plurality of unidirectional layers, whereby each layer is made of a 840 dtex aramid yarn comprising 1.68 dtex filaments. The layers for the second stack are impregnated with a matrix mixture of approximately 60% Rovene® 4220 and approximately 40% Rovene® 4176. The first stack or the second stack can be arranged on the strike face or the body face.

In another preferred embodiment the first stack comprises a plurality of unidirectional layers made of a 840 dtex aramid yarn comprising 1.68 dtex filaments. The layers are impregnated with Rhoplex® E-358 as matrix material. In this embodiment the second stack comprises a plurality of unidirectional layers, whereby each layer is made of a 1100 dtex aramid yarn comprising 1.1 dtex filaments. The layers for the second stack are impregnated with a matrix mixture of approximately 60% Rovene® 4220 and approximately 40% Rovene® 4176. The first stack or the second stack can be arranged on the strike face or the body face.

All % values in the four above-named embodiments are volume values.

The invention is further elucidated by figures.

Figure 1 schematically shows a panel comprising a first kind of stack and a second kind of stack.

Figure 2 shows the influence of linear density in respect to the energy absorption.

In figure 1 schematically an antiballistic panel 3 is shown. The panel 3 comprises a first stack 1 and a second stack 2 each with one laminate. In the embodiment of figure 1 the first stack 1 – this means the first laminate (and also the second stack 2, this means the second laminate) is built up by a film layer 4, a first unidirectional fiber layer 5, a second unidirectional fiber layer 6 and another film layer 7. The first unidirectional fiber layer 5 and the second unidirectional fiber layer 6 are impregnated with a matrix material. The unidirectional fiber layers 5 and 6 are cross plied to each other, this means the fiber direction of the fiber layer 5 has an angle of approximately 90° in respect to the fiber direction of the fiber layer 6. In this embodiment the first stack 1 and the second stack 2 have the same elements

(two unidirectional fiber layers 5, 6, and two film layers 4, 7). It is also possible, that the first stack 1 comprises four fiber layers and the second stack 2 comprises two fiber layers or reverse. In all embodiments the first stack 1 distinguished from the second stack 2 in respect to the used fiber. The fiber layers 5, 6 and the film layers 4, 7 are laminated together to form the first stack 1. In general, it is preferred to laminate the fiber layers with or without the film layers together to build up a laminate for the first stack 1 and/or for the second stack 2. The laminates are preferably arranged over each other to form the first and/or second stack. This means inside the stack the laminates are preferably not bonded together.

Example

For the Example four laminates each consisting of four fiber layers are built up. Each fiber layer is a unidirectional fiber layer (UD), whereby the fiber direction of the fibers of the fiber layers in each laminate was 0°, 90°, 0°, 90°. As matrix system for each fiber layer Prinlin B7137 AL from Henkel was chosen, which consists of a styrene-isoprene-styrene (SIS) block copolymer. During manufacturing of the UD fiber layer, this water-based matrix system is applied via a kiss roll to the fiber (yarn) of the fiber layer and subsequently dried on a hot-plate. Matrix concentration was determined from the dry unidirectional fiber layer (i.e. the concentration based on dry yarn weight) and is given in Table 1. Four unidirectional fiber layers were laminated into a 4-ply laminate with one 10 µm LDPE film on each outer sides of the laminate (each laminate comprises two film-layers), by using the lamination conditions indicated in Table 1. In total, a 4-ply laminate with LDPE-film has propagated through the laminator three times: the first time for 2-ply lamination (this means two UD fiber layers were laminated together), the second time for 4-ply lamination (this means two 2-ply sheets were laminated to one 4-ply laminate) and the third time for LDPE-film lamination on the 4-ply. Temperature (T) and lamination speed (v) were kept at comparable levels

for each passage, pressure was varied and is indicated by respectively P1 (first lamination), P2 (second lamination) and P3 (third lamination) in Table 1. Areal density of the 4-ply construction with LDPE-film on both sides was determined according to ASTM D3776-96. The matrix content (wt.%) is based on dry fiber weight:

$$\text{Matrix content} = (\text{Matrix weight} / \text{dry fiber weight}) \times 100\%$$

Table 1: Lamination conditions and construction of the different laminates

Laminate	Yarn type	Lamination conditions					Matrix content (wt.%)	Areal density (g/m ²)
		T (°C)	P1 N/cm ²	P2 N/cm ²	P3 N/cm ²	v (m/min)		
Laminate 1	T2000 1100 dtex f1000	120	35	10	10	1	17.2	243
Laminate 2	T1000 1680 dtex f1000	120	35	10	10	2	16.3	244
Laminate 3	T2000 840 dtex f500	120	35	10	10	1	17.1	258
Laminate 4	D2600 1100 dtex f2000	120	35	10	10	1	17.2	255

All laminates (4-ply + LDPE-film on both outer sides) were tested at the same conditions. A first sensor was arranged in a distance of 12 cm of the laminate. A second sensor is arranged behind the laminate (in respect to the muzzle) in a distance of 12 cm from the laminate. The distance between muzzle and laminate was 30 cm. The first sensor and the second sensor measure the bullet speed. The bullet is fired from an air-pressure rifle. The laminates are cut into test sample pieces, whereby the typical test sample dimensions are 118 x 118 mm. The bullet type used is the lead-based Super H-point (field line) produced by RUAG Ammotec GmbH with a caliber of .22 (5.5 mm) and a weight of 0.92 g. The bullet's incoming speed can be varied in the range from 240 m/s to about 360 m/s.

By subtracting the bullet kinetic energy ($\frac{1}{2} \cdot \text{mass}_{\text{bullet}} \cdot v_{\text{bullet}}^2$) after propagation through the laminate from the bullet kinetic energy before shield propagation through the laminate and subsequently dividing by the areal density of the laminate, a specific energy absorption (SEA) can be determined.

First laminate

In the first laminate yarn Twaron Type 2000, f1000, 1100 dtex as yarn (fiber) material was used. The yarn has a linear density of 1100 dtex measured according to ASTM D1907 and a filament linear density of 1.1 dtex measured by ASTM D1577-07 option C-2, the elongation at break in % was 3.5 measured according to D7269 and the tensile modulus was 91 GPa measured according to ASTM D7269.

Second laminate

In the second laminate yarn Twaron Type 1000, f1000, 1680 dtex as yarn material was used. The yarn has a tensile modulus of 71 GPa measured according to ASTM D7269, the linear density is 1680 dtex for the yarn measured according to ASTM D1907 and 1.68 dtex for the filament measured by ASTM D1577-07 option C-2, the elongation at break in % was 3.6 measured according to D7269.

Third laminate

In the third laminate yarn Twaron Type 2000, f500, 840 dtex as yarn material was used. The yarn has a tensile modulus of 91 GPa measured according to ASTM D7269, the linear density of the yarn was 840 dtex measured according to ASTM D1907 and the filament density was 1.68 dtex measured by ASTM D1577-07, option C-2, the elongation at break in % was 3.5 measured according to D7269.

Fourth laminate

In the fourth laminate yarn Twaron D2600 (development type), f2000, 1100 dtex was used as yarn material. The yarn has a tensile modulus of 94 GPa measured

according to ASTM D7269, the linear density of the yarn was 1100 dtex measured according to ASTM D1907 and the linear density of the filament was 0.55 dtex measured by ASTM D1577-07, option C-2. The elongation at break was 3.6 % measured according to D7269.

In Figure 2 the specific energy absorption (SEA) of the laminates is shown as a function of incoming bullet speed. Curve 1' represents the specific energy absorption (SEA) in respect to the bullet speed for the first laminate (Twaron Type 2000, f1000, 1100 dtex). Curve 2' represents the specific energy absorption (SEA) in respect to the bullet speed for the second laminate (Twaron Type 1000, f1000, 1680 dtex) and curve 3' for the third laminate (Twaron Type 2000, f500, 840 dtex). Curve 4' represents the specific energy absorption (SEA) in respect to the bullet speed for the fourth laminate (Twaron D2600 (development type), f2000, 1100 dtex) It can be seen that the aim is to have an as high as possible SEA-value for each incoming bullet speed. The 1' curve represents the laminate made of a yarn with relative low yarn linear density but with a high filament linear density.

Comparable to this curve 1' the curve 4' is considered, which represent a laminate made of a yarn with low linear density (for the yarn) and very low filament linear density. It is shown, that especially in the high bullet speed area both yarns (1' and 4') have approximately the same SEA value. Due to the fact that the manufacturing of the yarn for the fourth laminate (represented by the curve 4') is expensive and complicated it is preferred to use the yarn of the first laminate (represented by the curve 1') in the front part of the stack for high incoming bullet speed.

Comparing curves 1' and 4' to curve 3' shows that for the depicted range of bullet speeds, relatively higher yarn titers (1100dtex), with relatively lower filament titers (0.55 dtex and 1.1 dtex) would be preferred over relatively lower yarn titers (840 dtex) with higher relatively higher filament titers (1.68 dtex). Higher yarn titers have a cost advantage over lower yarn titers, so both a ballistic and cost advantage.

Therefore, one way to reduce costs and to simultaneously increase the ballistic performance would be a hybrid structure with one stack of high yarn count/low filament count (e.g. 1100dtex f2000). This is unexpected because a person skilled in the art believes lower yarn titers are better. The reason the keep also a low yarn count/high filament count (840 dtex f500) in the panel is because the yarn-spreading process to a thin (more flexible) UD is less complicated, therefore it is easier to make more flexible layers with lower yarn titers and thus obtain a more flexible application.

Reference numbers

- 1 first stack
- 2 second stack
- 3 panel
- 4 film (film layer)
- 5 fiber layer
- 6 fiber layer
- 7 film (film layer)
- 1' curve
- 2' curve
- 3' curve
- 4' curve

Antiballistic panel

Claims:

1. Antiballistic panel (3) comprising at least a first stack (1) and a second stack (2), wherein the first stack (1) has a plurality of first laminates made of a first kind of yarn and the second stack (2) has a plurality of second laminates made of a second kind of yarn, wherein the first kind of yarn has a linear density of at least 1001 dtex measured by ASTM D1907 and a filament linear density of at most 1.2 dtex measured by ASTM D1577-07, option C-2 and the second kind of yarn has a linear density of at most 1000 dtex measured by ASTM D1907 and a filament linear density of at least 1.3 dtex measured by ASTM D1577-07 option C-2.
2. Antiballistic panel (3) according to claim 1, wherein each laminate of the first stack (1) and/or the second stack (2) comprises at least one unidirectional fiber layer (5, 6).
3. Antiballistic panel (3) according to claim 2, wherein the fibers of at least two unidirectional fiber layers (5, 6) of the laminate are arranged under an angle of 90° in respect to each other.
4. Antiballistic panel (3) according to claim 1, wherein each laminate of the first stack (1) and/or the second stack (2) comprises at least one woven fiber layer.

5. Antiballistic panel (3) according to any of the foregoing claims, wherein the panel (3) has a body face and a strike face and wherein the first stack (1) is arranged to the strike face and the second stack (2) is arranged to the body side of the panel (3).
6. Antiballistic panel (3) according to any of the claims 1-4, wherein the panel (3) has a body face and a strike face and wherein the second stack (1) is arranged to the strike face and the first stack (2) is arranged to the body side of the panel (3).
7. Antiballistic panel (3) according to any of the foregoing claims, wherein at least one laminate of the first and/or second stack (1, 2) has at least one film (4, 7) on its outer surface.
8. Antiballistic panel (3) according to any of the foregoing claims, wherein the first yarn has a breaking tenacity higher than 2250 mN/tex measured according to D7269 and the second yarn has a breaking tenacity lower than 2249 mN/tex measured according to D7269.
9. Antiballistic panel (3) according to any of the claims 1 to 7, wherein the second yarn has a breaking tenacity higher than 2250 mN/tex measured according to D7269 and the first yarn has a breaking tenacity lower than 2249 mN/tex measured according to D7269.

1/2

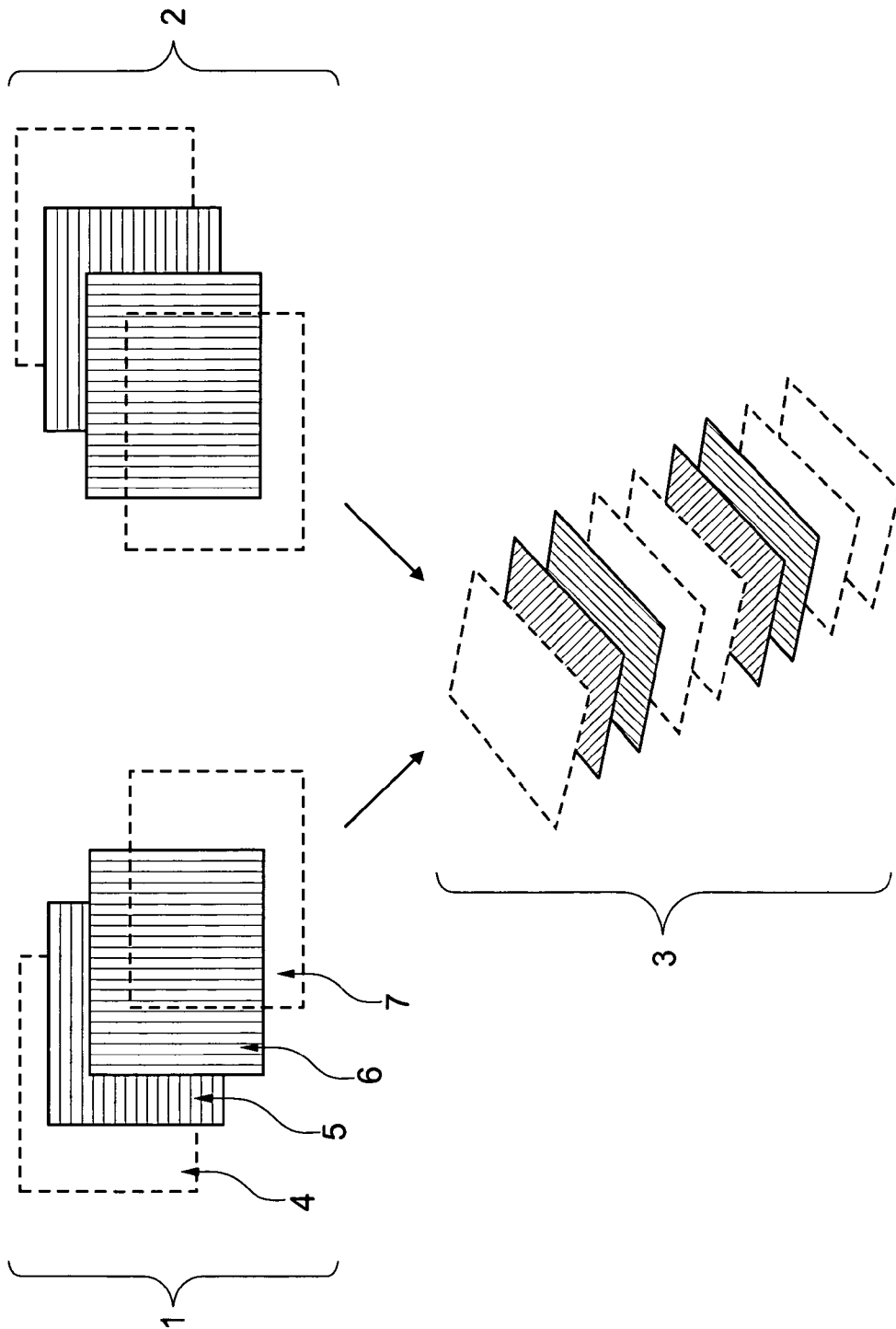


Fig. 1

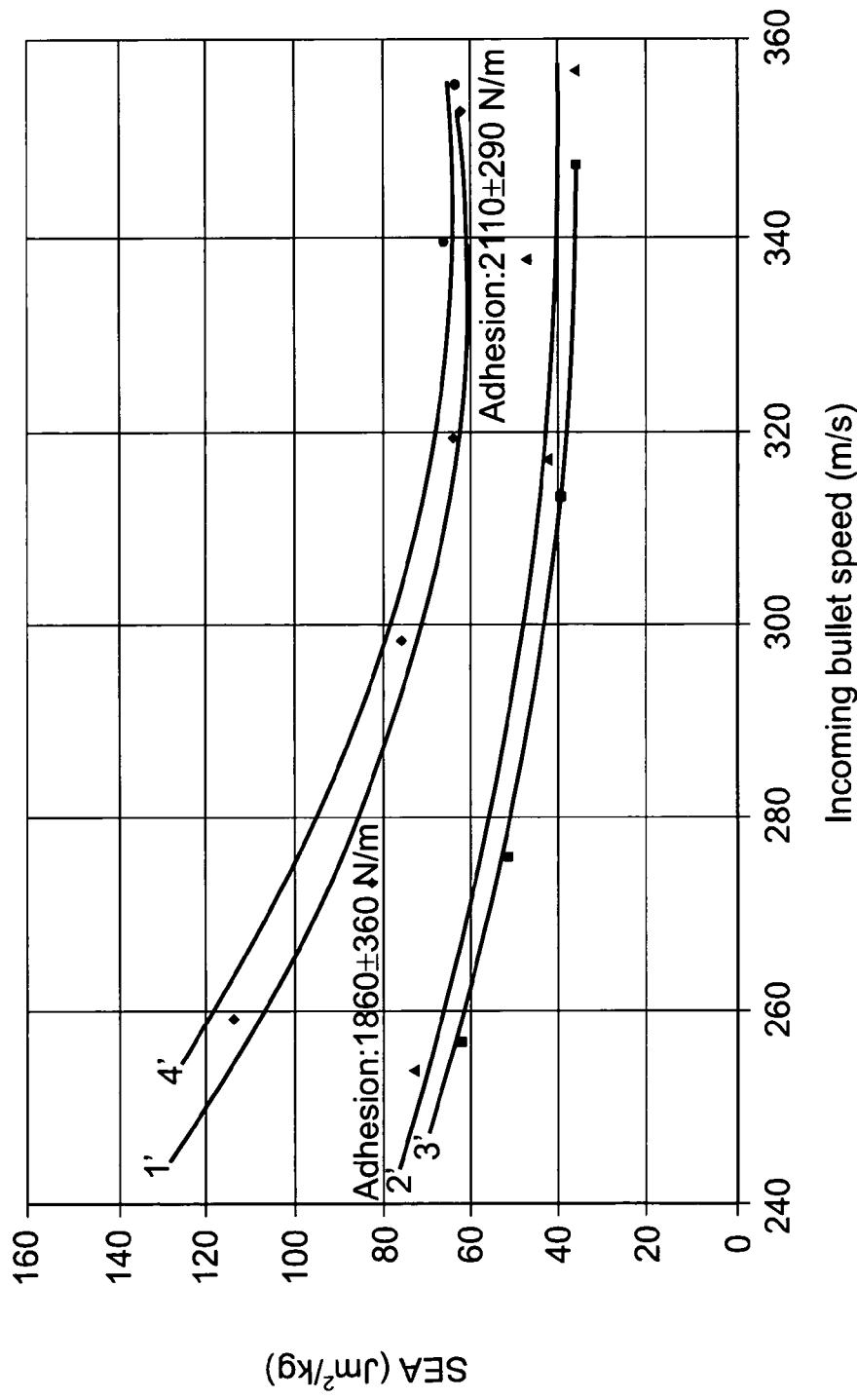


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/057611

A. CLASSIFICATION OF SUBJECT MATTER
INV. F41H5/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F41H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2005/003727 A1 (CHIOU MINSHON J [US]) 6 January 2005 (2005-01-06) cited in the application paragraphs [0019] - [0033] paragraphs [0044] - [0066] claims 1-24 figure 1	1-9
Y	DE 37 43 243 A1 (AKZO GMBH [DE]) 29 June 1989 (1989-06-29) cited in the application column 1; claims 1-4	1-9
A	WO 00/25614 A2 (SECOND CHANCE BODY ARMOR INC [US]) 11 May 2000 (2000-05-11) page 7 - page 13; figures 4,5,8	1



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search

16 May 2012

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29/05/2012

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2012/057611

Patent document cited in search report		Publication date		Patent family member(s)		Publication date
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