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(54) **Impact protective multi-layered fabric**

(57) The invention refers to an impact protective multi-layered fabric (9) comprising a pile of layers of a dry-fabric material, wherein at least one of said layers (1) is conformed to have least one closed fold (3) extending longitudinally across the layer (1), said closed fold (3) having first and second walls (5,6) substantially facing each other, and wherein said first and second walls (5,6) are stitched to each other by means of at least one yarn (7) of a dry-fabric material. Preferably, the first and sec-

ond walls (5,6) of the closed fold, are stitched to each other by means of two or more stitching lines (8) are arranged one above the other within the closed fold (3), such as when an object (2) impact on the fabric layer (1), the stitches (7) of the stitching lines (8) break sequentially one after the other, such the energy absorption capability of the layer is increased in a simple manner and without increasing its weight.

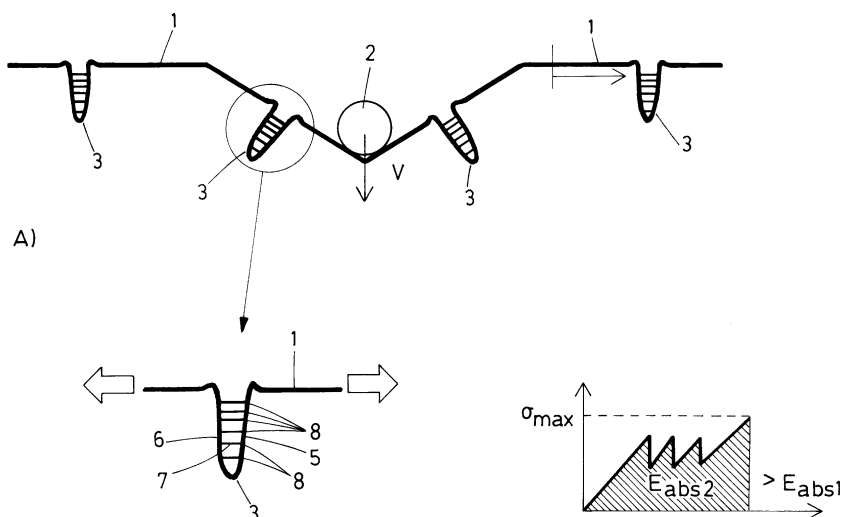


FIG. 2

B)

Description

Object of the invention

[0001] The present invention refers to impact absorbing woven fabrics for impact protection or ballistic applications.

[0002] An object of the present invention is to increase the impact energy absorption capability of a dry-fabric material, namely a textile material, without increasing the weight of the same.

Background of the invention

[0003] To form woven fabrics, two distinct groups of yarns are interwoven with each other, generally warp yarns run length-wise and weft yarns runs transversally to the warp yarns. For some ballistic applications, two or more layers of woven fabric are bonded together to produce a multi-layer structure, for example various layers may be layered up and then joined together by a resin. In other types of fabrics, multiple layers of woven fabric are stacked and then stitched together.

[0004] In the case of a bullet-proof jackets (soft protection), the layers can be stacked without any resin, and in the case of ballistic protection for vehicles (hard protection), the layers can be bonded together with a resin.

[0005] The most widespread type of fabric used in the field of impact protections in particular for intermediate and high speed impacts including ballistic protection, are dry-fabrics (Aramid i.e. Kevlar®, Ultra High Molecular Weight Poly Ethylene, PBO, etc.). The architecture of these protections consists typically in a stack of layers, each of them being 2D woven layers.

[0006] The behaviour of dry-fabrics when impacted is shown in Figure 1. The impact pushes the layer (1) out of plane (drawing 1A) and they react as a membrane absorbing the impact load in tension. The layer (1) breaks when the absorbed energy (Eabs1) reaches the ultimate tensile strength absorbing energy (α max) and decelerating the impactor (2) (drawing 1 B).

[0007] It is always desirable to increase the capability of this type of fabrics to absorb impact energy, but without increasing the weight of the material.

Summary of the invention

[0008] The invention improves the energy absorption capability of dry fabrics, by folding a fabric layer to form one or more folds or loops (in a cross-sectional view), and by stitching the loops, such as, when the fabric layer receives an impact, the fold would open or deploy and the stitches would break sequentially, thereby absorbing impact energy.

[0009] One aspect of the invention refers to a fabric structure capable of providing protection against impacts, wherein the fabric structure is formed by a plurality of woven layers of a dry-fabric material, placed on top of

each to form a pile or stack of layers. The invention is characterized in that at least one of said layers of the pile of layers, is conformed such as the layer forms at least one closed fold in the form of a pocket, which extends longitudinally across the layer, for example extending from one edge of the layer to the opposite edge.

[0010] A dry-fabric is a textile material without resin, that is, a material formed by fibers grouped to form strings, wherein these strings are interlaced.

[0011] Said pocket-like fold of that layer, has first and second walls placed one in front of the other, and these two walls are stitched to each other by means of at least one yarn or thread of a dry-fabric material. These two walls are stitched in the entire extension or at least a major part of the extension of the closed fold.

[0012] Preferably, first and second walls of the closed fold, are stitched to each other by means of several stitching lines, such as each stitching line extends along the closed fold, that is, each stitching line is placed according to the longitudinal direction of the closed fold. The stitching lines within the same closed fold, are arranged one above the other.

[0013] Due to the provision of the folds in the fabric layer, and the way the folds are stitched by means of several stitching lines one above the other, when an object impact on the fabric, the plurality of layers forming the same would expand such as the fold would be forced to unfold or deploy, and the stitching lines would break sequentially, from the one closer to the entrance of the fold towards the one closer to the bottom of the same.

[0014] In this way, the impact energy absorption capability of a conventional dry-fabric material is improved in a very simple manner, and without significantly increasing the weight of the same, since the only component added with respect to a prior art fabric, are the yarns for stitching the folds, but the weight of these yarns is not significant.

[0015] The fabric of the invention can be used for protecting a part of an aircraft against engine debris, from intermediate to high speed impacts, especially for protecting an aircraft fuselage in the case of an Open Rotor aircrafts, against accidental blade release threats.

[0016] The invention can also be applicable for engine debris protections of any type of engine (Turbofan, Turboprop, gas generator, etc) and even other more classical (low speed) impact threats, even for ballistic protections for personal or material shielding.

Brief description of the drawings

[0017] Preferred embodiments of the invention are henceforth described with reference to the accompanying drawings, in which:

Figure 1.- shows the behavior of a conventional dry-fabric material during the impact of an object. Drawing A shows the elastic deformation (represented by arrows) of a dry-fabric layer due to the impact, and

drawing B is a graph representing the impact energy absorption dynamic, wherein α is the energy absorbed by the fabric layer shown in the figure.

Figure 2.- shows a similar representation than figure 1 but corresponding to a fabric layer according to the invention.

Figure 3.- shows a schematic representation of a portion of a fabric layer according to the invention, wherein drawing A is a perspective view of the portion, and drawing B is a side elevational view.

Figure 4.- shows a schematic representation in a cross-sectional view, of two alternatives of a multi-layered fabric structure according to the invention.

Preferred embodiment of the invention

[0018] Drawing 2A shows a dry-fabric layer (1) for impact protection conformed to have at least one closed fold (3), obtained by folding the layer (1) along a folding (straight) line (4) across the layer, such as the major part of the layer (1) remains substantially flat and at least one closed fold (3) in the form of a channel or pocket is formed in the layer, having first and second walls (5,6) substantially facing each other.

[0019] Each closed fold (3) extends across the layer (1) in a longitudinal direction from one edge to the other edge (1',1'') of the layer. Furthermore, the first and second walls (5,6) of each closed fold (3), are stitched to each other by means of one or more yarns (7) made of a dry-fabric material, that is, a textile material. First and second walls (5,6) are in contact with each other due to the stitching, although in the figures are shown spaced apart from each other for the sake of clarity of the illustration.

[0020] The stitching is designed in a way that the stitches would break sequentially, that is, one after the other, until the stress in the layer archives its maximum tensile strength. Preferably, as shown in figures 3, the first and second walls (5,6) of the closed fold (3), are stitched to each other by means of two or more stitching lines (8), each stitching line extending along the closed fold and in major part of the length of the same, and wherein said stitching lines (8) are arranged one above the other.

[0021] This arrangement of the stitching lines (8) can be seen more clearly in drawing 3B, wherein it can be seen that each stitching line (8) is lying on an imaginary plane, and all the planes are parallel to each other.

[0022] When an object (2) impact the layer (1), this is expanded by the impact energy as illustrated by arrows in drawing 2A, such as the closed fold (3) opens and the stitches would break sequentially, that is, first the stitches of stitching line (8) closer to the major part of the layer (1) would break, then the stitches of the second stitching line (8), then thirds, and so on until the stitches of the stitching line (8) closer to the bottom of the closed fold

(3) are broken. After all the stitches are broken, the layer (1) would absorb more energy conventionally as explained previously with respect to drawing 1 A.

[0023] In this way, the energy absorption capability of the layer of the invention (Eabs2). is increased with respect to the prior art (Eabs1), as it observed in the graph of drawing 2B compared with the graph of drawing 1 B, such as (Eabs2) >> (Eabs1). The graph of drawing 1 B, has a serrated shape, wherein each peak corresponds to the energy absorbed by one stitching line (8).

[0024] This configuration of the dry fabric layer according to the invention, improve the protection performance of any dry fabric of the prior art in a very simple manner and more importantly, without increasing its weight.

[0025] Preferably, a pile or stack of fabric layers (1a,1b,1c) are provided forming a multi-layered structure (9) as shown in drawings 4A,B, wherein all the layers (1 a, 1 b, 1 c) of the structure or only some of them are provided with closed folds (3). At least one of the layers (1 a,1 b,1 c) comprises two or more closed folds (3), each closed fold extends longitudinally across the layer in which there are formed, and wherein the two or more closed folds are arranged substantially parallel to each other. All the folds of the multi-layered structure (9), are arranged in the same longitudinal direction.

[0026] Any possible relative position between closed folds (3) of different layers, is possible. In the embodiment of drawing 4B, the closed folds (3) of different layers (1a,1b,1c) are arranged right one above the other and are aligned in groups defining a grid-like pattern. In the embodiment of drawing 4A, the closed folds (3) of different layers (1 a, 1 b, 1 c) are interleaved.

[0027] In some preferred embodiments as the one shown in drawing 4A, the closed folds (3) are bended such as the first and second walls (5,6) of each closed fold, are substantially parallel with the layer (1a,1b,1c) in which they are formed. Alternatively, as shown in drawing 4B, first and second walls (5,6) the closed folds (3) are substantially perpendicular or straight to the layer(1a,1b,1c) in which they are formed.

[0028] In some cases, as the one shown in drawing 4A the layers are in contact which each other, however, in other cases (drawing 4B), there may be a gap or space between adjacent layers, such as adjacent layers are not in contact directly with each other, in order to allow the closed folds to deploy easily without adjacent layers rubbing with each other.

[0029] The layers of the pile of layers may be joined together by means of stitches provided a specific positions of the pile, as to maintain the pile together, however those stitches would not provide resistance to impacts.

[0030] Other preferred embodiments of the invention, include any combination of the above-mentioned features, namely bended and/or perpendicular closed folds, and/or interleaved or grip-like closed folds distribution.

[0031] Preferred materials for the woven fabric are:

- Aramida, commercially available as: Kevlar®, Twar-

- on®,
- Ultra High Molecular Weight Polyethylene, commercially available as: Dyneema®, Spectra®
 - glass fiber,
 - p-phenylene-2,6-benzobisoxazole, commercially available as: Zylon®.

[0032] Preferred materials for the stitching yarn are:

- Aramida fiber
- Glass fiber
- Ultra High Molecular Weight Polyethylene, commercially available as: Dyneema®, Spectra®

[0033] Other preferred embodiments of the present invention are described in the appended dependent claims and the multiple combinations of these claims.

Claims

1. Impact protective multi-layered fabric comprising a pile of layers of a textile material, **characterized in that** at least one of said layers is conformed to have least one closed fold extending longitudinally across the layer, said closed fold having first and second walls substantially facing each other, and wherein said first and second walls are stitched to each other by means of at least one yarn of a textile material.
2. Fabric according to claim 1 wherein the first and second walls of the closed fold, are stitched to each other by means of two or more stitching lines, each stitching line extending along the closed fold and in major part of the length of the same, and wherein said stitching lines are arranged one above the other.
3. Fabric according to claim 1 or 2 wherein said at least one layer comprises two or more closed folds, each closed fold extending longitudinally across the layer, and wherein the two or more closed folds are arranged substantially parallel to each other.
4. Fabric according to any of the preceding claims comprising two or more layers with two or more closed folds, and wherein the closed folds of different layers are arranged one above the other and are aligned.
5. Fabric according to any of the preceding claims comprising two or more layers with two or more closed folds, and wherein the closed folds of different layers are interleaved.
6. Fabric according to claim 4 or 5 wherein the closed folds are bended such as the first and second walls of each closed fold, are substantially parallel with the layer in which they are formed.

7. Fabric according to claim 4 or 5 wherein the closed folds are substantially perpendicular to the layer in which they are formed.

8. Fabric according to any of the claims 4 to 7, where there is space between adjacent layers, such as adjacent layers are not in contact directly with each other.

9. Fabric according to any of the preceding claims, wherein the layers are woven fabric made of a material selected from a list comprising: aramida, Ultra High Molecular Weight Polyethylene, glass fiber, and p-phenylene-2,6-benzobisoxazole.

10. Fabric according to any of the preceding claims, wherein the yarn for stitching the closed folds is made of a material selected from a list comprising: aramida fiber, glass fiber, and Ultra High Molecular Weight Polyethylene.

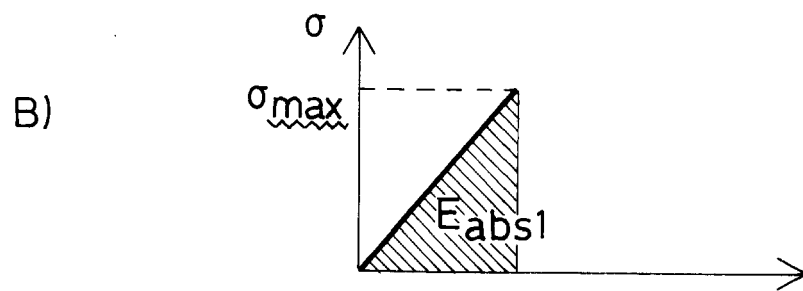
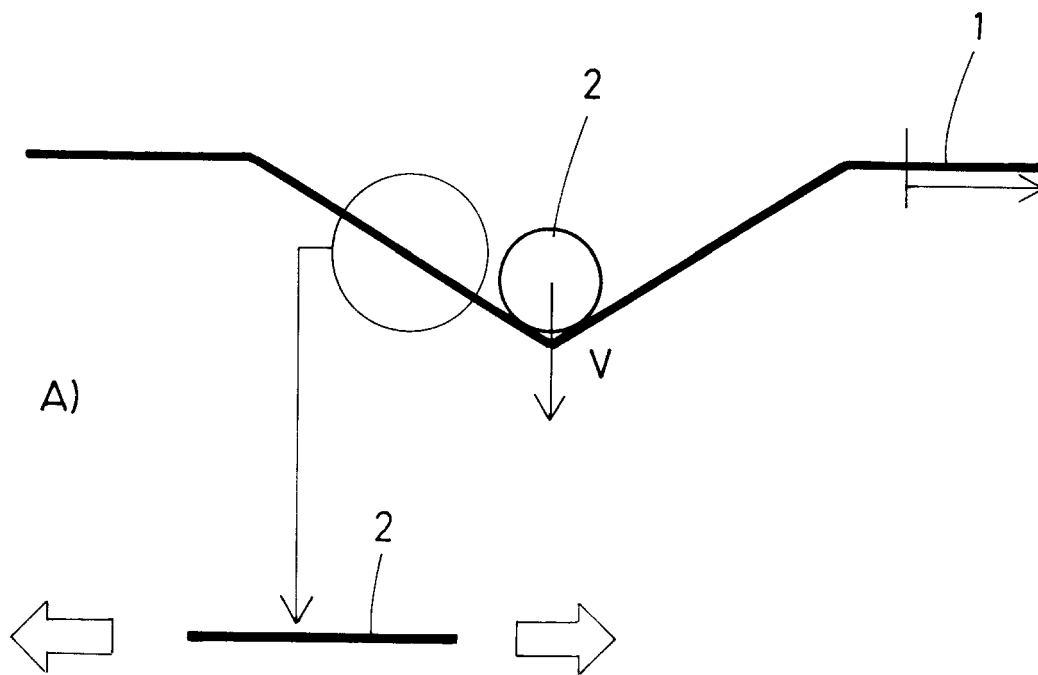
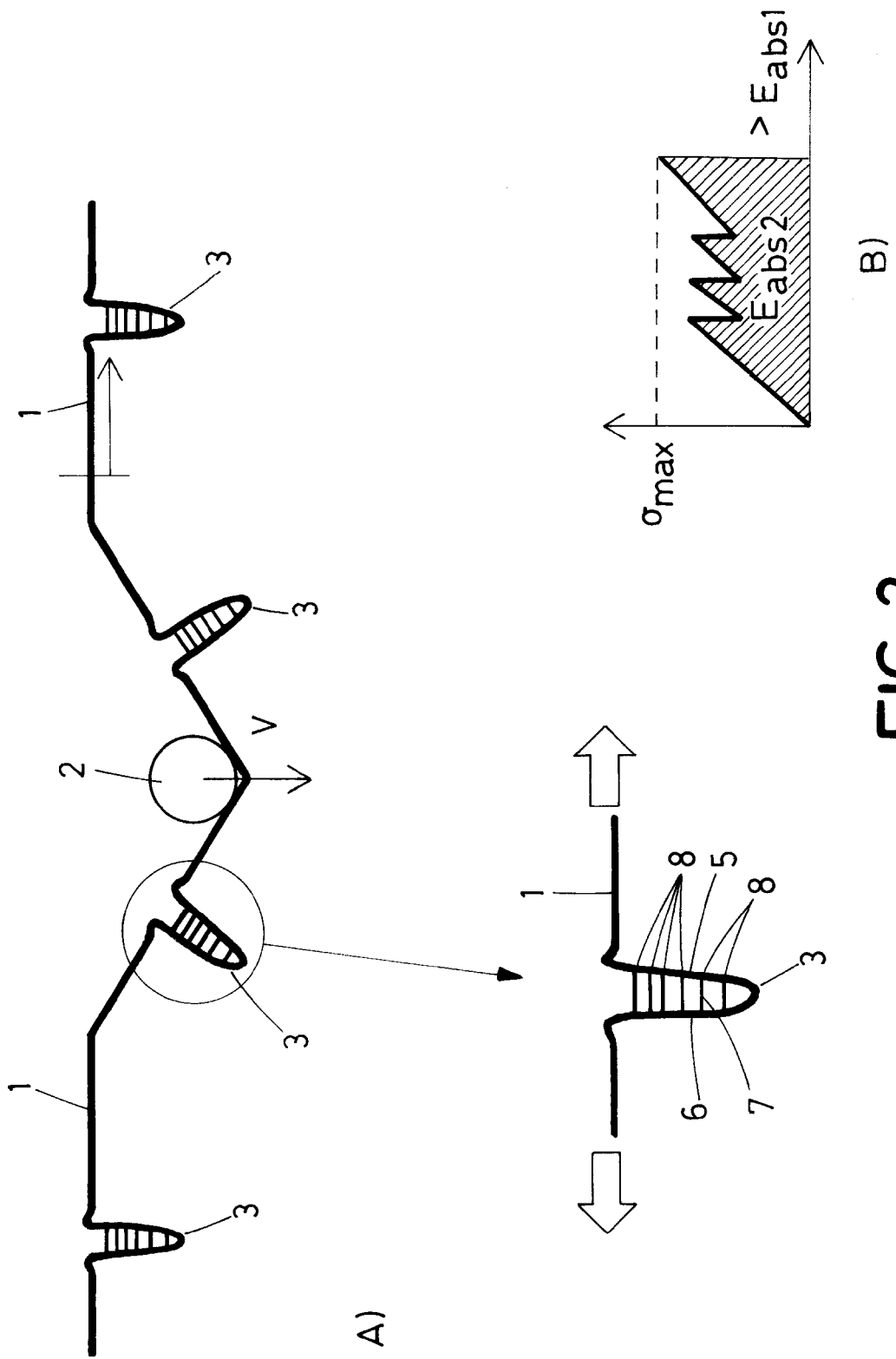


FIG.1



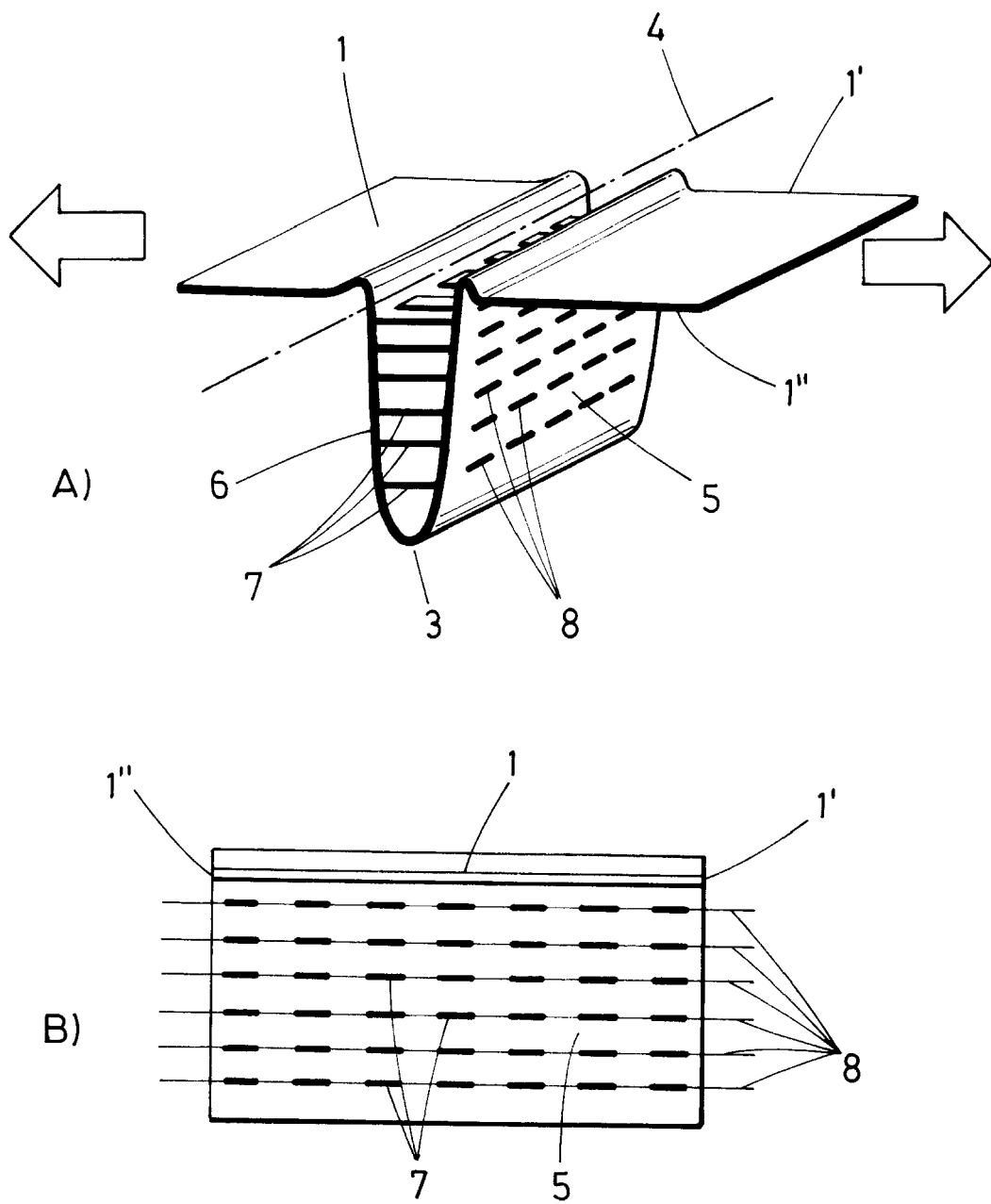


FIG.3

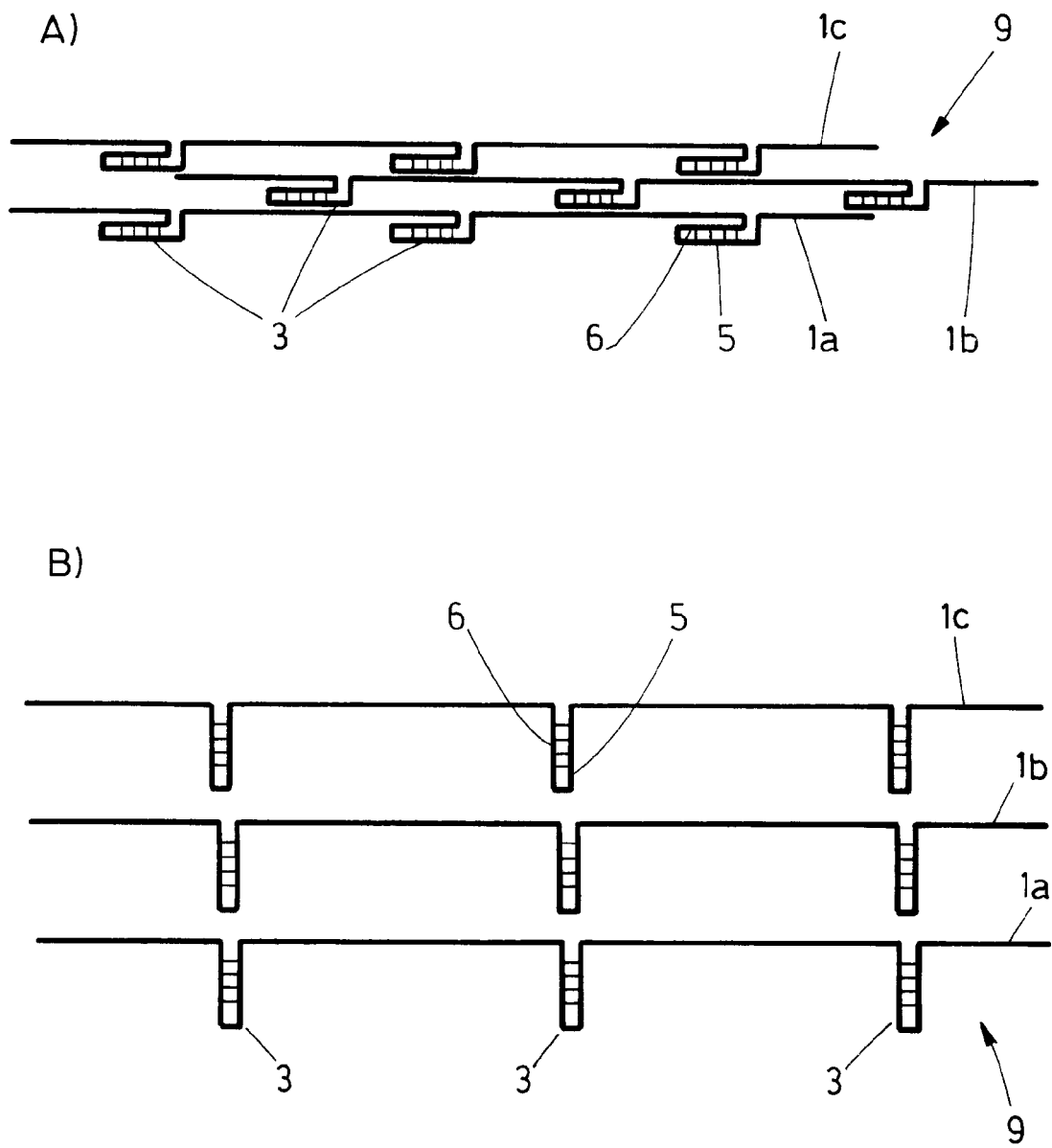


FIG.4



EUROPEAN SEARCH REPORT

Application Number
EP 14 38 2500

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A	US 5 723 201 A (CZETTO JR PAUL [US]) 3 March 1998 (1998-03-03) * column 3, line 61 - column 4, line 52; claim 1; figure 1 *	1,3,6,9	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			F41H D03D
Place of search		Date of completion of the search	Examiner
The Hague		19 May 2015	Beaufumé, Cédric
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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