



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
02.10.2019 Bulletin 2019/40

(51) Int Cl.:
D03D 11/00 (2006.01) B24D 11/00 (2006.01)

(21) Application number: **18164287.7**

(22) Date of filing: **27.03.2018**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
 Designated Extension States:
BA ME
 Designated Validation States:
KH MA MD TN

(72) Inventors:
 • **WHITEHEAD, Brent**
Bacup, Lancashire OL13 8GX (GB)
 • **TYLER, Michael**
Harrogate, HG1 3DN (GB)
 • **DAVIES, Mark**
Sketty, Swansea SA2 8LE (GB)
 • **WIXMERTEN, Bodo**
4123 Allschwil (CH)

(71) Applicant: **Habasit AG**
4153 Reinach (CH)

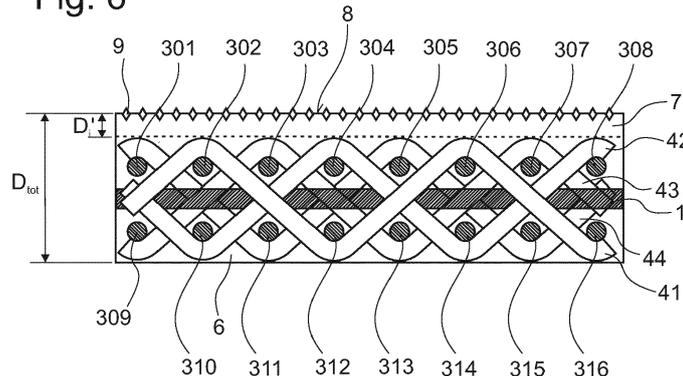
(74) Representative: **Bohest AG**
Holbeinstrasse 36-38
4051 Basel (CH)

(54) **FABRIC AND ABRASIVE PRODUCTS CONTAINING IT**

(57) A woven fabric comprising: a) A first layer of first uncrimped weft multifilaments (301-308) b) a second layer of second uncrimped weft multifilaments (309-316); wherein for each of the first uncrimped weft multifilaments (301-308) there is one corresponding second uncrimped weft multifilament (309-316), and vice versa, to form successive multifilament pairs (301/309, 302/310, 303/311, 304/312, 305/313, 306/314, 307/315, 308/316) of first and second uncrimped weft multifilaments; c) crimped warp filaments (41-44) having four different weave types c1 - c4, but each weave type consisting of entwining around first uncrimped weft multifilaments; passing between first and second uncrimped weft multifilaments; entwining around second uncrimped weft multifilaments; and passing again between first and second uncrimped weft multifilaments; d) uncrimped warp filaments (4)

passing between first (301-308) and second (309-316) uncrimped weft multifilaments of all multifilament pairs (301/309, 302/310, 303/311, 304/312, 305/313, 306/314, 307/315, 308/316); and optionally furthermore e) crimped antistatic warp filaments having one of the weave types c1-c4; provided that crimped warp filaments of all four weave types c1, c2, c3 and c4 defined above are present; wherein the fabric does not comprise any other crimped warp filaments, besides the crimped warp filaments (41-44) and optional crimped antistatic warp filaments. This fabric has good resistance to shear delamination of an impregnation 6 and/or a top layer 7 impregnated into the fabric, in either warp or weft direction, or both. Accordingly the fabric can be used in abrasive products such as abrasive belts, pads or disks.

Fig. 6



Description

TECHNICAL FIELD

5 **[0001]** The present application relates to fabric containing abrasive products.

PRIOR ART

10 **[0002]** Abrasive products are widely established and used in a variety of industries, such as aerospace, automotive equipment manufacturing, general industries, marine, metal working, paint preparation, precision grinding and finishing, primary metal, thermal spraying, transportation heavy equipment and woodworking.

15 **[0003]** Abrasive products may comprise of a base fabric, which is usually of polyester, cotton or aramid, a fabric coated layer which may e.g. be of rubber, elastomer, thermoplastic or thermoset materials which are either/or chemically or physically attached to the base fabric and a top layer comprising of various abrasive compounds and particles. Categories of abrasive products are, without limitation: wet/dry bands, file, narrow, portable, super abrasive and micro-finishing, wide and flat finishing belts and materials. Abrasive products may be in the form of pads, disks or belts.

20 **[0004]** Abrasive products inevitably experience a strong shear stress during their usage. The shear occurs because of the adherence of the backside of the abrasive product to the moving support and because of the friction between the front, abrading side of the abrasive product and the surface of the application to be abraded. The two forces acting on the backside and the front side of the abrasive product point in opposite directions, thus causing shear inside the abrasive product. This shear may be unidirectional, if the abrasive product is an abrasive belt running in only one direction while abrading the application to be abraded. The shear may however also be bidirectional, if the abrasive product is e.g. a pad which is moved in two directions, in particular in an approximately circular motion, over the application to be abraded.

25 **[0005]** JP 2013/240839 discloses an abrasive cloth containing a fabric base material which may be a plain, twill or satin weave. The warps are at least in part core-sheath fibres. The cloth is used in an abrasive belt.

[0006] JP 2011/093083 discloses a laminated polishing pad comprising a multifilament hard-twist-yarn textile and a base material whose Asker A hardness is 60. The textile may be plain weave, twill weave or satin, wherein plain weave is preferable in view of strongest binding force of warp and weft.

30 **[0007]** WO 2012/042040 mentions that in coated abrasives in the form of "sheets, belts, mop discs, flap discs" for bonding the abrasives "mainly phenolic resins are used" if high performance is needed, otherwise "urea resins and also animal glue", and for wet grinding "epoxy, urethane or alkyd resins".

35 **[0008]** US 2010/0323574 discloses a fabric having 4 layers of weft filaments extending in levels N1, N3, N5 and N7; warp fibres A, B and C all having the same weave type and being interwoven with said weft filaments of levels N1, N3, N5 and N7; warp fibres G, H and I all having the same, second weave type, and also being interwoven with said weft filaments of levels N1, N3, N5 and N7; further weft filaments extending in levels N2, N4 and N6; and warp filaments D, J, E, K, F and L not being interwoven with any weft filaments. This fabric is for use in producing composite material parts such as stays, rods and struts of landing gear.

40 **[0009]** GB 1 390 603 discloses a fabric containing upper and lower layers of weft filaments, reinforcing wires (extending in the warp direction), warp-wise extending yarns running in parallel with the reinforcing wires and not being interwoven with the upper and lower weft filaments, binder weft yarns being interwoven with both the upper and lower weft filaments, and warp yarns being interwoven either only with the upper weft filaments or only with the lower weft filaments. It also discloses a conveyor belt comprising that fabric and being impregnated with an elastomeric material, preferably a PVC plastisol.

45 **[0010]** The present invention aims to provide improved fabrics for abrasive products and abrasive products containing them.

SUMMARY

50 **[0011]** The present invention provides

[1] A woven fabric comprising:

- 55 a) A first layer (A) of first uncrimped weft multifilaments running essentially in parallel to each other and being spaced apart from each other by a distance D;
 b) a second layer (B) of second uncrimped weft multifilaments running essentially in parallel to each other and being spaced apart from each other by said distance D;
 wherein for each of the first uncrimped weft multifilaments there is one corresponding second uncrimped weft multifilament, and vice versa, to form successive multifilament pairs, each such successive multifilament pair

being designable with a unique and ascending integer index N;

c) crimped warp filaments having one of the following weave types c1 - c4:

c1 - entwine around first uncrimped weft multifilaments of all multifilament pairs with indexes N fulfilling $(N \bmod 4) = 0$, such indexes N being designated as N_A ; pass between first and second uncrimped weft multifilaments of all multifilament pairs with indexes N fulfilling $(N \bmod 4) = 1$, such indexes N being designated as N_B ; entwine around second uncrimped weft multifilaments of all multifilament pairs with indexes N fulfilling $(N \bmod 4) = 2$, such indexes N being designated as N_C ; and pass between first and second uncrimped weft multifilaments of all multifilament pairs with indexes N fulfilling $(N \bmod 4) = 3$, such indexes N being designated as N_D ;

or

c2 - entwine around second uncrimped weft multifilaments of all multifilament pairs with said indexes N_A ; pass between first and second uncrimped weft multifilaments of all multifilament pairs with said indexes N_B ; entwine around first uncrimped weft multifilaments of all multifilament pairs with said indexes N_C ; and pass between first and second uncrimped weft multifilaments of all multifilament pairs with said indexes N_D ;

or

c3 - pass between first and second uncrimped weft multifilaments of all multifilament pairs with said index N_A ; entwine around first uncrimped weft multifilaments of all multifilament pairs with said indexes N_B ; pass between first and second uncrimped weft multifilaments of all multifilament pairs with said indexes N_C ; and entwine around second uncrimped weft multifilaments of all multifilament pairs with said indexes N_D ;

or

c4 - pass between first and second uncrimped weft multifilaments of all multifilament pairs with said indexes N_A ; entwine around second uncrimped weft multifilaments of all multifilament pairs with said indexes N_B ; pass between first and second uncrimped weft multifilaments of all multifilament pairs with said indexes N_C ; and entwine around first uncrimped weft multifilaments of all filament pairs with said indexes N_D ;

d) uncrimped warp filaments passing between first and second uncrimped weft multifilaments of all multifilament pairs; and

e) optionally, crimped antistatic warp filaments having one of the weave types c1, c2, c3 or c4 defined above;

provided that crimped warp filaments of all four above defined weave types c1, c2, c3 and c4 are present;

wherein the fabric does not comprise any other crimped warp filaments, besides said crimped warp filaments and said optional crimped antistatic warp filaments.

[2] The fabric of above [1], wherein each uncrimped warp filament is separated in weft direction from the next uncrimped warp filament by an even number of crimped warp filaments, said even number being at least 2.

[3] The fabric of above [1] or [2], wherein each uncrimped warp filament is sandwiched in weft direction by two immediately adjacent crimped warp filaments.

[4] The fabric of one of above [1] to [3], wherein the crimped warp filaments of weave types c1 and c2 defined in above [1] are always present pairwise and immediately adjacent to each other in weft direction, and the crimped warp filaments of weave types c3 and c4 defined in above [1] are always present pairwise and immediately adjacent to each other in weft direction.

[5] The fabric of one of above [1] to [4], wherein the numerical ratio of crimped warp filaments c) to uncrimped warp filaments d) is in the range of 4:1 to 12:1.

[6] The fabric of one of above [1] to [5], wherein the crimped warp filaments c) and the uncrimped warp filaments d) are arranged in repetitive units in weft direction, in which repetitive units the order in which the uncrimped warp filaments d) and the crimped warp filaments of above weave types c1, c2, c3 and c4 are arranged in weft direction is always the same.

[7] The fabric of one of above [1] to [6], comprising the crimped antistatic warp filaments e).

[8] The fabric of one of above [1] to [7], consisting of first uncrimped weft multifilaments a), second uncrimped weft multifilaments b), crimped warp filaments c), uncrimped warp filaments d) and optional crimped antistatic warp filaments e).

[9] An abrasive product comprising:

i) a fabric according to any one of above [1] to [8] which is impregnated with an impregnation comprising or consisting of a thermoplastic, thermoplastic elastomer, thermoset, elastomer or a mixture thereof;

ii) immediately adjoining to one side of the impregnated fabric a first top layer with a first topmost surface comprising or consisting of the same thermoplastic, thermoplastic elastomer, thermoset, elastomer or mixture thereof as in the impregnation in the fabric, but being devoid of fabric, and

iii) a first particulate abrasive material embedded into the first topmost surface of the first top layer.

[10] The abrasive product of above [9], which is an endless abrasive belt.

[11] The abrasive product of above [9], furthermore comprising:

- iv) immediately adjoining to the other side of the impregnated fabric a second top layer with a second topmost surface and comprising or consisting of the same thermoplastic, thermoplastic elastomer, thermoset, elastomer or mixture thereof as in the impregnation (6) in the fabric, but being devoid of fabric; and
- v) a second particulate abrasive material embedded into the second topmost surface of the second top layer.

[12] An abrasive product comprising:

- i) a fabric according to any one of above [1] to [8] which is impregnated with an impregnation comprising or consisting of a thermoplastic, thermoplastic elastomer, thermoset or elastomer or a mixture thereof;
- ii) optionally, immediately adjoining to one side of the impregnated fabric, a first cover layer comprising or consisting of the same thermoplastic, thermoplastic elastomer, thermoset, elastomer or mixture thereof as in the impregnation in the fabric, but being devoid of fabric;
- iii) adjoining to said one side of the impregnated fabric, or, if the first cover layer is present, to said first cover layer a first prefabricated abrasive sheet with a first top sheet surface containing first abrasive particles embedded into the first top sheet surface.

[13] The abrasive product of above [12], furthermore comprising:

- iv) optionally, immediately adjoining to the other side of the impregnated fabric, a second cover layer comprising or consisting of the same thermoplastic, thermoplastic elastomer, thermoset, elastomer or mixture thereof as the impregnation in the fabric, but being devoid of fabric;
- iv) adjoining to said other side of the impregnated fabric, or, if the second cover layer is present, to said second cover layer, a second prefabricated abrasive sheet with a second top sheet surface containing second abrasive particles embedded into the second top sheet surface.

[14] The abrasive product of above [12] or [13], which is an abrasive pad or abrasive disk.

[15] The abrasive product of one of above [11] to [14], wherein the impregnation is comprises or consists of a thermoplastic or thermoplastic elastomer, in particular a TPU.

BRIEF DESCRIPTION OF THE FIGURES

[0012]

Figs. 1-3 are schematic representations of an embodiment of the fabric of the invention, namely Fig. 1 as a cross-sectional view in warp direction, Fig. 2 as a top view, and Fig. 3 again as cross-sectional view, but with only one crimped warp filament, either under unsheared condition (top of Fig. 3) or under *attempted* 20° shear (bottom of Fig. 3); Fig. 5 contains schematic representations of the fabric of the invention of Fig. 1, as a cross-sectional views in weft direction;

Figs. 6 and 7 are schematic cross-sectional views of an embodiment of an abrasive belt and of an abrasive pad or disk of the invention, respectively, each containing the fabric of Fig. 1.

DETAILED DESCRIPTION OF THE INVENTION

[0013] This invention provides to use a matrix of a thermoplastic, thermoset or elastomer material or mixture thereof, which matrix is flooded directly into the unidirectional reinforced multi-layer woven fabric component woven joined layers, providing a fully impregnated, physical entanglement of matrix and fabric, wherein the fabric is embedded and entangled in the matrix. Such entanglement aids in minimising layer separation, improves the polymer matrix bonding/adhesion characteristics and resistance to product ingress/commination issues and generally improves belt performance and service life, through good wear characteristics whilst providing good integral and dimensional flexibly.

[0014] The motion of inventive abrasive products over the good to be abraded may be either in the warp or the weft direction of the fabric, or both. In one special embodiment the motion may be approximately, or exactly, circular. The inventive fabric and the abrasive products of the invention containing it exhibit equally good resistance to shear delamination when shearing is in either warp direction or weft direction. This is surprising because the inventive fabric differs

in both weave structure and filament density in warp direction from weave structure and filament density in weft direction. The differences in weave structure are e.g. because one of the directions of the fabric (warp or weft direction, typically the warp direction) must also satisfy the requirements of a traction layer in an abrasive belt; this requirement is not necessary in the other direction (weft or warp direction, typically the weft direction). From the sole point of view of equally good resistance to shear delamination in both warp and weft direction a fabric having identical weave structure and filament count in both warp and weft directions would be most desirable.

[0015] Since the inventive fabric offers equally good resistance to shear delamination in either warp direction or weft direction, the orientation of the fabric within the inventive abrasive products with respect to the predominant, or sole, abrasive motion direction does not matter. If the abrasive product is however an abrasive belt, then it is preferred that the warp direction of the fabric is in the travel direction of the belt.

[0016] A possible theoretical explanation for the improvement in resistance to shear delamination in warp direction of the inventive fabric will be given with reference to Figs. 1-4. The fabric of the invention firstly offers good resistance to shear delamination in weft direction because all weft filaments are multifilaments, engaging more intimately with an impregnation adhering to them than monofilaments possibly could. A possible further theoretical explanation for the improvement in resistance to shear delamination in weft direction will be given with reference to Fig. 5.

[0017] In the inventive fabric all uncrimped weft filaments are multifilaments (designated in the following as "uncrimped weft multifilaments"). The uncrimped weft multifilaments are preferably made of polyester, such as PET. The titer of the uncrimped weft multifilaments, particularly if made of polyester such as PET, is preferably in the range of 670 to 2100 dtex. Also preferably, the tenacity of the uncrimped weft multifilaments is preferably in the range of 15 to 250 cN/tex, more preferably in the range of 30 to 100 cN/tex and most preferably of 60 to 80 cN/tex. Also preferably, their heat shrinkage (percentual length reduction under heating for 2 min at 180°C) is in the range of 0.5 to 15%, more preferably of 0.5 to 5% and most preferably of 1 to 2%. Also preferably, the uncrimped weft multifilaments may preferably have a slight or S- or Z-twist, or no twist at all, with the number of turns per metre preferably being in the range of 0 to 50, more preferably of 0 to 30 and most preferably of 0 to 10. The uncrimped weft multifilaments may optionally be spun together with staple fibres, such as polyester or a natural fibre such as cotton, e.g. by the known "core-spinning" process (see e.g. US 2 992 150 A), to further enhance the adhesion of the impregnation thereto. Preferably however, the uncrimped weft multifilaments are devoid of such staple fibres. The impregnation adheres sufficiently to such weft multifilaments even in the absence of staple fibres, by virtue of the overall inventive fabric.

[0018] The fabric of the invention contains first and second uncrimped weft multifilaments of the abovementioned type. To each of the first uncrimped weft multifilaments there is one corresponding second uncrimped weft multifilament, and vice versa, to form successive multifilament pairs, to each of which is assignable an integer index N. This index N is arbitrary, provided that it increases with the order of the successive multifilament pairs in warp direction. The index N may be in a range of N_{\min} to N_{\max} , wherein N_{\min} is the lowest possible index typically assigned to the first multifilament pair of the specimen of fabric in question, and wherein N_{\max} is the highest possible index typically assigned to the last multifilament pair of the specimen of fabric in question. Whether a given index N is assigned the designation N_A , N_B , N_C or N_D depends on the result of the modulo 4 operation performed on N, which as used here is the remainder obtained by the so-called "Euclidean integer division" of N by 4.

[0019] All crimped warp filaments are preferably also multifilaments, spun yarns or a combination of multifilament yarns and staple fibres spun together by the commonly known "core-spinning" process. Any such crimped warp filaments are preferably devoid of natural fibres, such as cotton, jute, hemp or cellulose-based fibres. The impregnation adheres sufficiently to the inventive fabric even in the absence of such natural fibres. The crimped warp filaments are preferably made of polyester such as PET. The titer of the crimped warp filaments is preferably in the range of 550 to 2000 dtex, particularly if made from polyester such as PET. Also preferably, the tenacity of the crimped warp filaments is preferably in the range of 15 to 250 cN/tex, more preferably in the range of 15 to 40 cN/tex and most preferably of 20 to 30 cN/tex. Also preferably, their heat shrinkage (percentual length reduction under heating for 2 min at 180°C) is in the range of 0.5 to 15%, more preferably of 5 to 15% and most preferably of 8 to 12%. Also preferably, the crimped warp yarns may preferably have an S- or Z-twist, with the number of turns per metre preferably being in the range of 0 to 400, more preferably of 250 to 400 and most preferably of 300 to 400. Alternatively, their degree of twisting may preferably be in the range of 5 to 15%, more preferably of 7 to 13% and most preferably of 9 to 11%.

[0020] The crimped warp filaments have one of four different weave types c1-c4. These four weave types are as in following Table 1, using the above indexes N_A - N_D to define the multifilament pairs in question:

Table 1

| weave type | N_A | N_B | N_C | N_D |
|------------|---|---|---|---|
| c1 | entwine around first uncrimped weft multifilament of such multifilament pairs | pass between first and second uncrimped weft multifilaments of such multifilament pairs | entwine around second uncrimped weft multifilament of such multifilament pairs | pass between first and second uncrimped weft multifilaments of such multifilament pairs |
| c4 | pass between first and second uncrimped weft multifilaments of such multifilament pairs | entwine around second uncrimped weft multifilaments of such multifilament pairs | pass between first and second uncrimped weft multifilaments of such multifilament pairs | entwine around first uncrimped weft multifilaments of such multifilament pairs |
| c2 | entwine around second uncrimped weft multifilaments of such multifilament pairs | pass between first and second uncrimped weft multifilaments of such multifilament pairs | entwine around first uncrimped weft multifilament of such multifilament pairs | pass between first and second uncrimped weft multifilaments of such multifilament pairs |
| c3 | pass between first and second uncrimped weft multifilaments of such multifilament pairs | entwine around first uncrimped weft multifilament of such multifilament pairs | pass between first and second uncrimped weft multifilaments of such multifilament pairs | entwine around second uncrimped weft multifilament of such multifilament pairs |

[0021] That is, the above weave types c1, c4, c2 and c3 differ only in that their entwining around first uncrimped weft multifilaments, their passing between first and second uncrimped weft multifilaments, their entwining around second uncrimped weft multifilaments and their passing between first and second uncrimped weft multifilaments is permuted cyclically over the indexes N_A , N_B , N_C and N_D when going from c1 to c4 to c2 to c3.

[0022] It is preferred for the fabric of the invention that crimped warp filaments of above weave types c1 and c2 always appear pairwise and immediately adjacent to each other in weft direction, and that crimped warp filaments of above weave types c3 and c4 always appear pairwise and immediately adjacent to each other in weft direction.

[0023] The fabric of the invention contains crimped warp filaments of all weave types c1-c4 discussed above. Preferably it contains crimped warp filaments of each of the four weave types c1, c2, c3 and c4 in equal numbers, more preferably also in equal numbers within each above discussed repetitive unit.

[0024] All uncrimped warp filaments are preferably multifilaments, or a plurality of such multifilaments, e.g. 3-8 such multifilaments, arranged in parallel and immediately adjacent to each other. The uncrimped warp filaments are preferably made of polyester, in particular of PET, or aramid. The titer of the uncrimped warp filaments (or, if there is a plurality of multifilaments, the sum of the titer of all them) is preferably in the range of 500 to 5000 dtex. More preferably, if the uncrimped warp filaments are of polyester such as PET, their titer (or, if there is a plurality of multifilaments, the sum of the titer of all them) is in the range of 550 to 2000 dtex; if they are of aramid, then their titer (or, if there is a plurality of multifilaments, the sum of the titer of all them) is more preferably in the range of 440 to 3500 dtex. Also preferably, the tenacity of the uncrimped warp filaments (or, if there is a plurality of multifilaments, the overall tenacity of the entire plurality) is preferably in the range of 15 to 250 cN/tex, more preferably in the range of 30 to 100 cN/tex and most preferably of 60 to 80 cN/tex. Also preferably, their heat shrinkage (percentual length reduction under heating for 2 min at 180°C) is in the range of 0.5 to 15%, more preferably of 0.5 to 5% and most preferably of 1 to 2%. Also preferably, the uncrimped warp multifilaments may preferably have a slight S- or Z-twist, or no twist, with the number of turns per metre preferably being in the range of 0 to 400, more preferably of 50 to 300 and most preferably of 70 to 140.

[0025] It is more preferred for the fabric of the invention that the crimped warp filaments and the uncrimped warp filaments are present in repetitive units in weft direction, wherein the order in which crimped warp filaments with weave type c1, crimped warp filaments with weave type c2, crimped warp filaments with weave type c3, crimped warp filaments with weave type c4 and uncrimped warp filaments are arranged in weft direction is always the same.

[0026] Preferably also, each uncrimped warp filament is separated in weft direction from the next uncrimped warp filament by an even number of crimped warp filaments, wherein that even number is at least 2. More preferably here, any crimped warp filaments immediately adjacent have either the above discussed weave types c1/c2 or the weave types c3/c4.

[0027] More preferably also each uncrimped warp filament is sandwiched in weft direction by two immediately adjacent crimped warp filaments. That is, two successive uncrimped warp filaments are preferably never immediately adjacent to each other in weft direction; there is preferably always at least one, preferably two (see above) crimped warp filaments in between.

[0028] There are typically 4 to 12 crimped warp filaments per uncrimped warp filament, wherein the specific ratio of 12:1 applies in particular to the above mentioned embodiment of the uncrimped warp filament being a plurality of filaments arranged in parallel and immediately adjacent to each other. Another most preferred embodiment is a ratio of crimped warp filaments to uncrimped warp filaments of 4:1.

[0029] In one specific preferred embodiment of the fabric the ratio of crimped warp filaments to uncrimped warp filaments may be 4:1. If therein these warp filaments occur in repetitive units, wherein the order of the filaments in these repetitive units is always the same, then exemplary such orders are C(c1)-C(c2)-UC-C(c3)-C(c4) or any cyclic permutation thereof, wherein C designates crimped warp filaments and UC designates an uncrimped warp filament, and the weave types are indicated in parentheses.

[0030] In another preferred embodiment of the fabric the ratio of crimped warp filaments to uncrimped warp filaments may be 12:1. If therein the warp filaments occur in repetitive units, wherein the order of the filaments is always the same, then exemplary such orders are C(c3)-C(c4)-C(c1)-C(c2)-C(c3)-C(c4)-UC-C(c1)-C(c2)-C(c3)-C(c4)-C(c1)-C(c2) or any cyclic permutation thereof, wherein C and UC are as above, and the weave types are indicated in parentheses.

[0031] All of the foregoing uncrimped weft, crimped warp and uncrimped warp multifilaments may preferably be in the form of bicomponent fibres. Subclasses of such bicomponent fibres are those wherein a plurality of filaments of a higher-melting polymer are combined with a plurality of filaments of lower-melting polymer; or a plurality of filaments of a higher-melting polymer is embedded in, or sheathed by, a lower-melting polymer. Here, "higher melting" and "lower melting" are relative to each other. The purpose of such bicomponent fibres is that either upon weaving or thereafter, the bicomponent fibres are heated such that only the lower-melting material softens, fusing adjacent multifilaments together, in particular at the overcrossing sections thereof. Upon re-cooling, a fabric results which, due to the hotmelt adhesive joining of the overcrossing sections, exhibits increased resistance towards deformation under shear, and thus towards shear delamination.

[0032] Examples of bicomponent fibres wherein a plurality of filaments of a higher-melting polymer is embedded in lower melting polymer are the so-called "islands-in-a-sea" filaments; examples of bicomponent fibres wherein a plurality of filaments of a higher-melting polymer is sheathed by a lower molecular weight polymer are the "core-sheath" fibres, e.g. of mass ratio core:sheath of 50:50 to 80:20; and either concentric or eccentric. Preferred are said core-sheath bicomponent fibres, most preferred of the concentric type.

[0033] The difference in melting point or melting interval may be controlled e.g. by having the same type of polymer, but with two different molecular weights, or by combining two chemically different but compatible polymers. Examples of polymer material pairs for the higher melting and lower melting polymer are e.g. higher and lower molecular weight polyester, in particular PET; polyester and polyamide-6,6; polyamide-6,6 and copolyester.

[0034] Combining two different types of polymer in one bicomponent multifilament may result in a self-curling or self-crimping of the bicomponent fibres, which is less preferred for the purposes of the invention. In order to counteract that it may be preferable that in a cross-section of the bicomponent fibre either the two pluralities of filaments are uniformly distributed; or the regions of lower melting polymer are uniformly distributed, or are arranged such that they have an at least approximate C_n symmetry, wherein the rotation axis runs along the central axis of the bicomponent fibre and n is an integer number equal or greater than 2. In the case of the most preferred concentric core-sheath bicomponent fibres, n would be infinity.

[0035] All these types of bicomponent fibres as such are conventional and well known in the art.

[0036] The fabric of the invention may optionally contain crimped antistatic warp filaments e) of one of the above defined weave types c1-c4. These antistatic filaments preferably are spun yarns, e.g. of carbon fibres, or are conductive polyester, cotton, nylon or aramid fibres having a metallic conductor adhered thereto, coated there onto or embedded therein. Such conductive fibres are as such conventional. The tenacity of the crimped antistatic warp filaments is preferably in the range of 15 to 250 cN/tex, more preferably in the range of 15 to 40 cN/tex and most preferably of 20 to 30 cN/tex. Also preferably, their heat shrinkage (percentual length reduction under heating for 2 min at 180°C) is in the range of 0.5 to 15%, more preferably of 5 to 15% and most preferably of 8 to 12%. Also preferably, the crimped antistatic warp filaments may preferably have an S- or Z-twist, with the number of turns per metre preferably being in the range of 0 to 400 and more preferably of 100 to 400. More preferably there is exactly one crimped antistatic warp filament separated by every four consecutive uncrimped warp filaments.

[0037] In warp direction the fabric of the invention does not comprise any other types of crimped filaments, besides the crimped warp filaments and optional crimped antistatic warp filaments with one of above weave types c1, c2, c3 or c4. More preferably, the fabric of the invention does in warp direction not comprise any other types of filaments, besides the crimped warp filaments and optional crimped antistatic warp filaments with weave types c1, c2, c3 or c4 and the uncrimped warp filaments. In weft direction the fabric of the invention preferably does not comprise any other filaments, besides the uncrimped first and second weft filaments. Most preferably, the fabric of the invention does not comprise any other filaments, besides the uncrimped first and second weft filaments, uncrimped warp filaments, crimped warp filaments and optional crimped antistatic warp filaments.

[0038] If the warp filaments occur in repetitive units, wherein the order of the filaments in these repetitive units is always

the same, and crimped antistatic warp filaments are also present, then preferably again these crimped antistatic warp filaments are included always at the same position within a repetitive unit. Apart from that, their number and position(s) in a repetitive unit is arbitrary. Preferably there is one such crimped antistatic warp filament per repetitive unit.

[0039] The fabric tensile of the overall fabric is preferably in the range of 4000 to 8000 N/50mm, more preferably of 5000 to 7000 N/50mm in warp direction and preferably 6000 to 9000 N/50mm, more preferably 6500 to 8500 N/50mm in weft direction.

[0040] A fabric of the invention being impregnated with a thermoplastic, thermoplastic elastomer, elastomer or thermoset may be a precursor to an abrasive product of the invention.

[0041] The thermoplastic as the impregnation may preferably be selected from the group consisting of thermoplastic polyolefins (such as polyethylene or polypropylene), substantially random ethylene/C3-12- α -olefin copolymers (examples of the α -olefin being 1-propene, 1-butene, 1-pentene, 1-hexene and 1-octene), thermoplastic polyamides, ethylene-vinylacetate copolymers, poly(vinylacetate) and PVC.

[0042] The thermoplastic elastomer as the impregnation may preferably be selected from the group consisting of thermoplastic elastomeric block copolymers (such as styrenic block copolymers, in particular styrene-butadiene-styrene, styrene-isoprene-styrene, styrene-ethylene/butylene-styrene and styrene-ethylene/propylene-styrene block copolymers), copolymers of hard blocks of medium density polyethylene and of soft blocks of ethylene/ α -olefin copolymers, thermoplastic polyurethanes (such as copolymers of polyester diols or polyether diols with diisocyanates), polyether-ester block amides and thermoplastic elastomeric ionomers.

[0043] The thermoset as the impregnation may e.g. be a phenol-formaldehyde resin, a thermosetting polyurethane, an epoxy resin, or a polycarboxylic acid such as a poly(meth)acrylic acid which is crosslinked by a glycol, such as glycerol.

[0044] The elastomer as the impregnation may e.g. be a polyurethane, a natural rubber, polyisoprene, polybutadiene, styrene-butadiene rubber (SBR), nitrile-butadiene rubber (NBR), ethylene-propylene-diene rubber (EPDM) or an acrylate rubber. All of these may be crosslinked or vulcanized preferably simultaneously during the impregnation step or thereafter. The elastomer may beforehand have been blended with a thermoplastic as exemplified above.

[0045] The impregnation is preferably made of a thermoplastic elastomer, more preferably of a TPU. Suitable TPU's may be obtained by reacting diisocyanate-containing hard block segments with polyester diol soft block segments.

[0046] Such impregnated fabric may e.g. be obtained by the following steps:

a) a fabric of the invention is provided;

b) one of the sides of the fabric is sealed with a relatively thin layer of the thermoplastic or thermoplastic elastomer, typically using a solution thereof in a suitable solvent, such as DMF, acetone, dimethyl sulfoxide or other, and using a suited coating method such as knife over air, knife over air, or kiss-roller or transfer coating;

c) the solvent is evaporated, optionally under heat or other types of radiation and/or under reduced pressure, to provide a thin primer coating of the thermoplastic or thermoplastic elastomer on the concerned fabric side; this coating is still porous and gas-permeable;

d) on the opposite side of the fabric a relatively thick film coating of thermoplastic, thermoset or elastomer or mixture thereof as in the primer coating is applied, e.g. by calendaring or extrusion, and pushed into and through the fabric until it meets the primer coating; allowing entrapped gas to escape through the primer coating, whereby the impregnated fabric is obtained.

[0047] The finished impregnated fabric will typically have impregnating material on both sides of the inventive fabric, such as that no filament portions of the fabric are exposed to the environment. On one of the sides of the fabric the impregnation will form a continuous layer of geometrically well defined surface, this continuous layer completely embedding the fabric. This continuous layer may preferably also comprise a first top layer consisting only of impregnation material and being completely devoid of fabric. This first top layer is, when the above described process is used, normally on the side of the fabric onto which the relatively thick film coating of thermoplastic, thermoset, elastomer or mixture thereof was applied by calendaring or extrusion. The thickness of this first top layer, if present, is designated as D_i and is typically in the range of 100 to 500 micrometres. If present, the first top layer will form said geometrically well defined surface. The thickness D_i may be determined using ultrasound reflection. Namely, an appropriate ultrasound probe may be placed onto said geometrically well defined surface. The time difference between the emission of an ultrasound pulse from the probe into the belt and the detection of the first ultrasound echo, which is reflected from the surface of the embedded fabric, can be measured. If the longitudinal speed of the ultrasound in the used thermoplastic or thermoplastic elastomer is known, then D_i can be determined. For the longitudinal speed of sound in the used thermoplastic or thermoplastic elastomer reference is made e.g. to the chapter 60 "Acoustic properties of polymers" of the "Physical Properties of Polymers Handbook", second edition, by James E. Mark, its Table 60.1 and the references cited there. Such belt thickness measurement devices and appropriate probes are in fact known and available on the market. An example is the 38DL Plus from NDT Instruments with a single element transducer as the probe.

[0048] Optionally, and as an optional step e) in the above described process, a sheet of the same thermoplastic,

thermoset, elastomer or mixture thereof as used in the impregnation can be laminated or calendared to the other side of the impregnated fabric. In the above described process this is the side that was initially sealed with the relatively thin layer of thermoplastic, thermoset, elastomer or mixtures thereof. This will then form on said other side of the fabric an optional second top layer with a second geometrically well defined topmost surface.

[0049] The abrasive product of the invention contains at least one type of particulate abrasive material. The particulate abrasive material(s) as such is(are) conventional. Examples of abrasive materials include, without limitation, alumina (e.g. fused aluminum oxide including brown aluminum oxide, heat treated aluminum oxide and white aluminum oxide; ceramic aluminum oxide; corundum; ruby; sapphire; or doped alumina), refractory carbides (e.g. silicon carbide; boron carbide; tungsten carbide; titanium carbide or cementite (Fe_3C)), refractory nitrides (e.g. boron nitride, titanium nitride, silicon nitride, zirconium nitride; tungsten nitride; vanadium nitride; chromium nitride; tantalum nitride or niobium nitride), chromia, alumina zirconia, diamond, iron oxide, titanium diboride, ceria, garnets (e.g. pyrope; almandine; spessartine; uvarovite and andradite), powdered glass, metal particulates and combinations thereof. The abrasive particles may typically have a mass median diameter (MMD) ranging from 0.01 to 30 micrometres, preferably from 0.05 to 10 micrometres, and more preferably from 0.1 to 5 micrometres, as obtainable by laser diffraction determination of the particle size distribution. The abrasive particles may typically have a Mohs' hardness of at least about 7, preferably of at least 8.

[0050] The abrasive product of the invention may be prepared by providing an impregnated fabric, as described above, and applying a particulate abrasive material, as described above. This may be done in several ways.

[0051] In a first preferred embodiment the abrasive product contains the abrasive particles embedded into the topmost surface(s) of the top layer(s) itself(themselves). The material of the impregnation, and thus of the top layer(s), is a thermoplastic, thermoset, elastomer or mixture thereof, thus a material that softens or melts upon heating. The topmost surface(s) of the top layer(s) may in one alternative be uniformly heated, such as with an array of IR lamps, to soften it(them) up to nearly its (their) melting point. Immediately following the heating the particulate abrasive is uniformly sprayed or dusted, such as by electrostatic spraying, onto the softened surface(s). Alternatively the abrasive particles may be electrostatically sprayed onto the still cold topmost surface(s) and this is then passed through heated calendar rolls to simultaneously soften the thermoplastic, thermoset, elastomer or mixtures thereof and to embed the abrasive particles into the softened surface(s). In either of these two alternatives after cooling, an abrasive article having the abrasive particles directly embedded into the topmost surface(s) is obtained. The overall thickness of each abrasive-containing top layer, D_i' , may again be determined using ultrasound reflection as outlined above for the top layer still devoid of abrasive particles. If the abrasive particles are very small with respect to the expected thickness of the abrasive-containing uppermost continuous top layer, e.g. when their mass median diameter (MMD, see above) is in the range of 0.01 to 0.5 micrometres, then the time difference between ultrasound pulse generation and the echo, reflected from the surface of the embedded fabric, can be taken. The D_i' will then be essentially the same as D_i discussed above. If the abrasive particles are of greater MMD, then the ultrasound probe will not lie directly on the outermost surface but on the apexes of the abrasive particles. In this case the time difference between the first echo, reflected from the outermost surface, and the second echo, reflected from the surface of the embedded fabric, can be taken.

[0052] If the particulate abrasive material is directly embedded into the thermoplastic, thermoset, elastomer or mixture thereof comprised in the top layer(s), as outlined above, then one maximally takes advantage of the enhanced resistance impregnation against delamination from the inventive fabric under shear stress, because there are no further layers and there is thus no concern about any other possible interlayer separations during use in abrasion.

[0053] A second preferred way to obtain an abrasive article of the inventions is to apply one or two prefabricated sheets containing abrasive particles, as described above, onto one or both of the surfaces of the impregnation (if no top layer(s) of the same thermoplastic or thermoplastic elastomer as in the impregnation is or are present) or onto the surface(s) of the top layer(s), if such top layer(s) is(are) present. Including the abrasive particles in the form of prefabricated sheets containing them may allow to take advantage of the diversity of such sheets that are available on the market and of the experience of the respective produces in manufacturing them in the desired uniformity. It may also allow to impart the abrasive article further mechanical rigidity, which is favourable in view of better abrasive action onto the substrate to be abraded.

[0054] In this second embodiment, the term "apply a prefabricated sheet containing abrasive particles" is firstly understood to mean to the joining of the compound of impregnated fabric / optional top layer(s) and the prefabricated abrasive sheet by means of heat and pressure, such as by heated calendaring rolls, wherein the impregnation material itself may act as a hotmelt adhesive, or with co-use of an additional, thermoplastic or thermosetting or elastomer adhesive or adhesion primer. It is secondly understood to mean the simple laying of the prefabricated abrasive sheet onto the compound of impregnated fabric / optional top layer(s) without any measures to effect a physical or chemical bonding between them, to obtain an abrasive article of the invention wherein the prefabricated abrasive sheet can easily be replaced once spent or worn down.

[0055] As in the first above described embodiment, each of the optional first and second top layer(s) will again have a thickness D_{i1} and D_{i2} , respectively, and each of the first and second prefabricated sheets containing abrasive particles will have a thickness D_{i1}' and D_{i2}' , respectively. Each of these thicknesses is again measurable by ultrasound as described

above, particularly also because the thermoplastic or thermoplastic elastomer of the impregnation and optional first and second top layer(s) will normally be different from the matrix material of the prefabricated abrasive sheet(s), so that a further ultrasound echo is obtained on each respective phase boundary.

5 [0056] The term "prefabricated sheet containing abrasive particles" may mean any planar sheet like material, such as in the form of sheets, ribbons, tapes or disks. These prefabricated sheets contain abrasive particles embedded in a plastic support, such as typically of polyester, optionally with use of an adhesive, or may be of the sandpaper type. The latter is in particularly preferred for the abovementioned abrasive articles without physical or chemical bonding to the compound of impregnated fabric / optional top layer(s).

10 [0057] If the prefabricated abrasive sheet is bonded to the compound of impregnated fabric / optional top layer(s) then the resistance to delamination of the resulting abrasive product under shear during use may be similar as in the above outlined first way of directly embedding abrasive particles into the impregnation.

15 [0058] If the prefabricated abrasive sheet is simply applied to the compound of impregnated fabric / optional top layer(s) without physical or chemical bonding then adhesion between them during use in abrasion occurs typically because of the pressure that the abrasive product will exert against the surface of the good to be abraded, taking advantage of the static coefficient of friction between surface of the impregnation and bottom side of the prefabricated abrasive sheet. If said bottom side has a notable surface roughness or surface unevenness, such as by an explicit surface profiling or embossing, then, during use in abrasion, that uneven bottom surface may in time start to snugly fit the surface of the impregnation or of the uppermost continuous top layer. The use in abrasion generates friction heat, and the impregnation, of moderate Shore A hardness at room temperature and becoming softer when heated, will in time slightly deform to match the said uneven bottom surface.

20 [0059] There are many companies that offer abrasive particles and/or prefabricated abrasive sheets on the market, examples being, at the time of filing of this application, Minnesota Mining & Manufacturing (USA), D.K. Holdings Limited (UK), KGS Diamond International AG (Netherlands, Portugal) and SIA Abrasives (Switzerland).

25 [0060] In any of the foregoing embodiments, the abrasive particles, whether as such or used in the form of a prefabricated abrasive sheets, may eventually cover only a fraction of the outermost surface of the abrasive product of the invention. Sections of the outermost surface that are not covered by abrasive particles or abrasive sheet may constitute recessed channels through which abraded material and/or excess friction heat may be removed. Furthermore, if only a fraction of the outermost surface is covered, then the pressure that is exerted onto the surface of the good to be abraded increases by the reciprocal of that fraction, if the remainder of the parameters of the abrading process are left unchanged.

30 [0061] The overall thickness of an abrasive product of the invention, D_{tot} , is typically in the range of 0.5 to 5 mm, preferably of 1 to 3 mm. The thickness D_{tot} can be measured with an ordinary gauge, if necessary by applying a weak overpressure such as of 0.2 bar.

35 [0062] The abrasive product of the invention can have any essentially sheet-like shape of sufficient surface such as to be able to abrade a sufficient portion of the surface of a good to be abraded. The abrasive product may be used in planar shape or wound up to a cylindrical shape. The abrasive product may be hand-driven or power-driven, e.g. by a power drill which has a circular rubber support disk onto which the abrasive product of the invention is fixed or laid upon. Preferably it has the shape of an abrasive belt, or of an abrasive disk or abrasive pad. In an abrasive belt of the invention the abrasive particles are preferably embedded directly into the topmost surface of a fabric-devoid top layer made of the same thermoplastic or thermoplastic elastomer as the impregnation in the fabric (see above). Abrasive belts are normally operated similar as an ordinary conveyor belt, that is, in endless shape using driving and idler pulleys. For an inventive abrasive belt it is preferred that it has abrasive particle coating only on one side (the outer side), but not at the other side facing said pulleys. The abrasive belts of the invention contain thermoplastic or thermoplastic elastomer and they can thus be made endless by any of the customary end-joining techniques for conveyor belts using that thermoplastic, thermoset, elastomer or mixture thereof as a hotmelt adhesive, such as by the so-called "finger end" or overlap joining technique. Abrasive pads are preferably planar and have preferably the shape of a square, rectangle, triangle, or of a sector of a circular arc or of a sector of a circle, preferably also with rounded edges. Abrasive disks of the invention have a preferably an essentially or exactly circular shape and are preferably intended to be used for circular abrasion motion. In abrasive pads or disks of the invention abrasive coatings may be applied to one or both sides of the impregnated fabric; preferably they are applied only to one side thereof. The abrasive coating is preferably applied in the form of prefabricated abrasive sheets, either directly to the impregnated fabric or to a fabric-devoid cover layer consisting of the same material as the impregnation.

45 [0063] The abrasive product of the invention can have, depending on the contained abrasive and shape, widely diverse applications. Non-limiting examples are deburring (such as deburring internal diameters), blending (such as blending corners), buffing, chrome stripping, cleaning, coating removal, descaling, sanding (such as drum sanding; edge sanding; mould sanding; wide belt sanding; portable belt sanding or stroke sanding), edge bevelling, edge seaming, finishing (such as contour finishing; fine finishing; flat area finishing; intermediate finishing; stainless steel finishing; straight line brushed finishing; superfinishing; weld removal finishing or power train micro-finishing), gate removal, grinding (such as high pressure grinding; light grinding; plate grinding; right angle grinding; sheet grinding; swing frame grinding; slab

grinding or centreless & cylindrical grinding), mill scale removal, parting line removal, polishing (such as plate polishing; polishing internal diameters; sheet polishing or coil polishing), prepping metal prior to paint, radiusing, refining, setting the grain, shaping, etc.

[0064] The resistance of the inventive fabric against delamination, when used in an abrasive article and the abrasive motion is in **warp** direction of the fabric, will now be discussed with reference to Figs. 1-4.

[0065] Fig. 1 (cross-sectional view) and Fig. 2 (top view) show an exemplary fabric of the instant invention. This fabric has uncrimped warp filaments 1, first and second uncrimped weft multifilaments (shown in cross-section in Fig. 1), designated with numerals 301-308 and 309-316, respectively, and crimped warp filaments 41-44. To each of the first uncrimped weft multifilaments 301 resp. 302 resp. 303 resp. 304 resp. 305 resp. 306 resp. 307 resp. 308 there is one corresponding second uncrimped weft multifilament 309 resp. 310 resp. 311 resp. 312 resp. 313 resp. 314 resp. 315 resp. 316, and vice versa, to form successive multifilament pairs 301/309, 302/310, 303/311, 304/312, 305/313, 306/314, 307/315, 308/316. Each of these successive multifilament pairs is designable with an integer index; e.g. according to the following Table 2:

Table 2

| multifilament pair | Exemplary index N for multifilament pair |
|--------------------|--|
| 301/309 | 239 (= N _D , because (N mod 4) = 3) |
| 302/310 | 240 (= N _A , because (N mod 4) = 0) |
| 303/311 | 241 (= N _B , because (N mod 4) = 1) |
| 304/312 | 242 (= N _C , because (N mod 4) = 2) |
| 305/313 | 243 (= N _D , because (N mod 4) = 3) |
| 306/314 | 244 (= N _A , because (N mod 4) = 0) |
| 307/315 | 245 (= N _B , because (N mod 4) = 1) |
| 308/316 | 246 (= N _C , because (N mod 4) = 2) |

[0066] Fig. 3 is a schematic side view of the crimped warp filament 41 of the fabric of Fig. 1, once (upper part of Fig. 3) without shear and once (lower part of Fig. 3) at *attempted* 20° shear. This crimped warp filament 41 has falling filament portions (one indicated with numeral 411) of a length V and rising filament portions (one indicated with numeral 412) of a length W, wherein W = V in the unsheared state.

[0067] If the fabric is sheared, the rising filament portions 412 come under tensile stress. However, if the uncrimped warp filament 1 and the crimped warp filaments 41-44 are assumed of reasonably high tenacity then the half pitch L and the length W of the rising filament portions 412 may be assumed unchanged in unsheared and sheared state. The falling filament portions 411, when under shear, come under compressible stress and their length V' becomes schematically shorter under that compressible stress.

[0068] This schematic shortened length V' of the falling filament portions 411 under shear is exactly calculable based on the shear angle, the filament diameters and the interfilamentous distances, and under said assumptions of L and W remaining constant as follows:

$$V' = \sqrt{W^2 + 4L\sin(\delta) \left(L\sin(\delta) - \sqrt{L^2\sin^2(\delta) + H^2} \right)} \quad (1)$$

wherein W is said length of the rising filament portions 412 (being equal in unsheared state and sheared state, being furthermore equal in unsheared state to the length V of the falling filament portions 411), this W being calculable as follows:

$$W = \sqrt{L^2 + H^2 - (X + Y)^2} \quad (2);$$

wherein L is said half-pitch, H is the distance in vertical direction by which the centres of adjacent uncrimped weft multifilaments are matched in corresponding pairs (e.g. 308/316); X is the diameter of the uncrimped weft multifilament(s) 301-316; Y is the diameter of the crimped warp filament 41; and δ is the shear angle.

[0069] For meaningful shear angles δ the sin(δ) is greater than or equal zero, and L and H are always greater than zero. Then always in (1):

$$L\sin(\delta) < \sqrt{L^2\sin^2(\delta) + H^2}$$

This means that the term in brackets in (1) is always smaller than zero, the V' calculated with (1) is always smaller than $W (=V)$, and the ratio $V':V$ is always smaller than 1.

[0070] At given H and δ , the term

$$4L\sin(\delta) \left(L\sin(\delta) - \sqrt{L^2\sin^2(\delta) + H^2} \right)$$

appearing in (1) becomes closer to zero with increasing half-pitch L , and the V' calculated with (1) at given H , X , Y , and δ becomes closer to W . Accordingly, the ratio of $V':V (=V':W)$ becomes closer to unity with increasing half-pitch L .

[0071] In the exemplary embodiment of Figs. 1-3, wherein $D = 15$ units, $L = 30$ units, $H = 15$ units, $X = 4.35$, $Y = 4.35$ units and $\delta = 20^\circ$, one obtains with the above formulae: $W = V = 32.39$ units, $V' = 26.29$ units, and $V':V (=V':W) = 0.831$. This corresponds to a schematic shortening of the falling filament portions 611 at *attempted* 20° shear of 16.9%.

[0072] The presumed real reaction of the falling filament portions 411 to such compressible stress is (for monofilaments) some bulging outwards from their longitudinal axis or (for multifilaments) some fluffing up of the individual filaments contained therein or some bulking up of the multifilament. This presumed reaction of the falling filament portions 411 to the compressible stress is believed to be a major reason for possible delamination of an impregnation adhering to these falling filament portions 411, and thus for delamination of such impregnation adhering to the warp filament 41. This presumed real reaction of the falling filament portions 411 to compressible stress cannot be adequately shown in Fig. 3. Instead Fig. 3 shows said schematic shortening of the length of the falling filament portions 411 from V , unsheared state, to V' , sheared state. The more pronounced the schematic shortening V' of the falling filament portions 411 is, the more pronounced said real reaction of the falling filament portions 411 to compressible stress is predicted to be.

[0073] If a crimped warp filament 5 which simply entwines around first and second uncrimped weft multifilaments, 301-308 and 309-316, respectively, in alternating manner, as shown in Fig. 4, without ever passing between any uncrimped weft multifilaments 301-316, was used in the inventive fabric, then the half pitch L for that alternatingly entwining crimped warp filament 5 would be equal to D and thus only 15 instead of 30. If the length W of its rising filament portions 52 could be assumed constant under shear and all other parameters were assumed identical as for Figs. 1-3 then one would obtain with the above formulae (1) and (2) for the falling filament portions 51 of such alternatingly entwining crimped warp filament 5 at a shear angle of 20° : $W = V = 19.35$ units, $V' = 12.42$ units and $V':V (=V':W) = 0.642$, which corresponds to a schematic shortening of these falling filament portions 51 at 20° shear of 35.8%. This is much more than the 16.9% observed for the crimped warp filament 41 of inventive fabric of Fig.1 and is indicative of a more significant real reaction of the falling filament portions 51 in such alternatingly entwining crimped warp filament 5 to compressible stress, and thus of a more significant tendency of an impregnation adhering to the falling filament portions 51 of such filament to delaminate under shear.

[0074] In the inventive fabric the half pitch L of the weave in warp direction is about twice the distance D between centres of adjacent uncrimped weft filaments, because there are always extra filament pairs which allow passing of the crimped warp filaments 41-44 between their first and second uncrimped filaments. The formula for calculating the schematic distance H' between the centres of first uncrimped weft multifilament (e.g. 303 or 308 in Fig. 3) and second uncrimped weft multifilament (e.g. 311 or 316 in Fig. 3) in any such multifilament pairs in sheared state of the fabric is:

$$H' = \sqrt{L^2\sin^2(\delta) + H^2} - L\sin(\delta) \quad (3)$$

wherein H , L and δ are as defined above.

Since L and H are always greater than zero, and since for meaningful shear angles δ the $\sin(\delta)$ is greater than or equal zero, the H' calculated with formula (3) becomes smaller with increasing half-pitch L . The H' by formula (3) is equal to H when the shear angle δ is zero and becomes smaller than H when δ is greater than zero. The greater the half pitch L is, the faster H' of formula (3) converges towards zero with increasing shear angle δ .

[0075] By the above behaviour of above formula (3) it is secondly possible to predict that, by virtue of H' becoming smaller with increasing shear angle δ , the said extra multifilament pairs (e.g. 303/311 in Fig. 3) will start to laterally compress the falling filament portions 411, which will partially counteract their said bulging outwards, bulking up or fluffing up, thus furthermore preventing delamination of the impregnation adhering to these falling filament portions 411.

[0076] By the above behaviour of above formula (3) it is thirdly possible to predict that, by virtue of H' converging faster towards zero with increasing half pitch L , the reduction of the distance H' will be more pronounced in the inventive fabric

of Figs. 1-3 than in a fabric having crimped warp filaments 5 as shown in Fig. 4, because for such simply alternating crimped warp filaments the half-pitch L is only equal to that distance D, not twice the distance D. Accordingly it is predicted that the inventive fabric of Figs. 1-3 cannot be sheared to the same extent as a fabric containing warp filaments 5, because of its tendency to become compressed (the more pronounced reduction of H') rather than becoming sheared. The schematic representation in the lower part of Fig. 3 actually predicts that the inventive fabric of Figs. 1-3 *resists* a shearing to 20°, in view of the graphical overlap of the uncrimped weft filaments 301-316 with the crimped warp filament 41 and with the uncrimped warp filament 1.

[0077] The above considerations were made specifically for the crimped warp filament 41 appearing in Figs. 1-2, but can be applied to any of the other crimped warp filaments 42, 43 and 44 shown therein, since they all have the same weaving type as crimped warp filament 41.

[0078] In view of all the foregoing the fabric of Fig. 1, when impregnated and formed into an abrasive product, is predicted to be less prone to shear delamination, when the abrasive motion is in warp direction of the fabric, than a fabric having alternately entwining warp filaments 5 as shown in Fig. 4.

[0079] Essential for this improved resistance to shear delamination under abrasive action in **warp** direction of the fabric is thus that the fabric of the invention contains both crimped warp filaments 41-44 of the weave type discussed for Fig. 1-2 and contains uncrimped warp filaments 1, but does not contain any crimped warp filaments 5 simply entwining around the first and second uncrimped weft multifilaments in alternating manner without ever passing between uncrimped weft filaments, as depicted in Fig. 4.

[0080] The improved resistance of the inventive fabric against delamination, when used in an abrasive article and the abrasive motion is in **weft** direction of the fabric, will now be discussed with reference to Fig. 5.

[0081] Fig. 5 shows four cross-sectional views of the inventive fabric of Fig. 1 in weft direction. The first cross-sectional view is through the successive multifilament pair with uncrimped weft multifilaments 302, 310; the second one through the successive multifilament pair with uncrimped weft multifilaments 303, 311; the third one through the successive multifilament pair with uncrimped weft multifilaments 304, 312; and the fourth one through the successive multifilament pair with uncrimped weft multifilaments 305, 313. In each of the four cross-sectional views a dashed box indicates a repetitive unit in weft direction. This repetitive unit in all cross-sectional views also comprises one crimped warp filament passing between first and second uncrimped weft multifilament of each successive multifilament pair: In the first and third cross-sectional views it is the crimped warp filament 43, and in the second and fourth cross-sectional views it is the crimped warp filament 42. The passing of the crimped warp filaments 42, 43 between first and second uncrimped weft multifilaments is indicated by vertical lines; these being upward solid and downward dashed if the crimped warp filaments 42, 43, upon passing between first and second uncrimped weft multifilaments, form a rising filament portion 412 (as discussed in Fig. 3); or these vertical lines being upward dashed and downward solid if the crimped warp filaments 42, 43, upon passing between first and second uncrimped weft multifilaments, form a falling filament portion 411 (as discussed in Fig. 3). The crimped warp filaments 42, 43, both pass between first/second uncrimped weft multifilaments 302/310, 303/311, 304/312 and 305/313, and entwine around first uncrimped weft multifilaments 302-305 and around second uncrimped weft multifilaments 310-313. So the crimped warp filaments 42, 43 cannot rotate at all around their central axis and thus firstly prevent an axial displacing movement of said first uncrimped weft multifilaments 302-305 and said second uncrimped weft multifilaments 310-313 in opposite directions. Such axial displacing movement would actually be favoured by the uncrimped warp filaments 1, which possibly could act as a roller, facilitating such axial displacing movement of said first uncrimped weft multifilaments 302-305 and said second uncrimped weft filaments 310-313 in opposite directions by rotation around their central axis. If the uncrimped weft multifilaments 302-305 and 310-313 are close enough, or come close enough upon shear in weft direction, the crimped warp filaments 42, 43 also prevent further axial displacement thereof in opposite directions by friction, since they cannot rotate.

[0082] If, as also shown in Fig. 5, the repetitive unit contains still further crimped warp filaments 41, 44 the inhibition of axial displacement of the uncrimped weft multifilaments 302-305 and 310-313 in opposite directions is even more pronounced, for the same reasons as discussed for the crimped warp filaments 42, 43.

[0083] In summary it is predicted that the fabric of Fig. 1 is also resistant to shear, and thus to shear delamination, in its **weft** direction.

[0084] The resistance to shear delamination predicted to be particularly pronounced if the direction of shear is simultaneously in **warp** direction (to bring about a stronger compression of the fabric, as discussed with reference to Fig. 3), and in **weft** direction (to use said stronger compression of the fabric, to cause increased friction between uncrimped weft filaments 302-305 and 310-313 and uncrimped warp filament 1, which in turn prevents shear in the weft direction, as discussed with reference to Fig. 5).

[0085] The resistance to shear delamination of the inventive abrasive products under abrasive action can easily be experimentally tested in a Taber abrader (Taber industries). Instead of the standardized Taber abrading wheels a custom abrading wheel of the same size, but containing as the abrasive outer face a ribbon of the abrasive product of the invention to be tested, is used. This setup allows to test for shear of the abrasive product of the invention in any direction of the weave of the fabric contained therein (warp, weft, or a combination of both). The ribbon only needs to be cut out

from the abrasive product of the invention in a suited orientation.

[0086] Fig. 6 is a schematic cross-sectional view of an abrasive belt of the invention containing the fabric of the invention, along its longitudinal direction, cutting through the uncrimped warp filament 1 and the first and second uncrimped weft multifilaments, 301-308 and 309-316, respectively. The longitudinal (warp) direction of the fabric is also considered to be the abrasive belt's travel direction. The first and second uncrimped weft multifilaments 301-308 and 309-316, respectively, are made of polyester and in the exemplified embodiment have a thickness of 0.25-0.45 mm. The uncrimped warp filament 1 is typically a multifilament made of polyester or, more preferable, of aramid. The crimped warp filaments 41-44 are typically multifilaments made of polyester and in the exemplified embodiment have a titer of 550 to 2000 dtex. There are typically 4 or 12 crimped warp filaments 41-44 per uncrimped warp filament 1. The abrasive belt has an impregnation 6, typically of a TPU, such as of Lubrizol's Estane® TPU types, and an uppermost continuous top layer 7 consisting of the same impregnation material as the impregnation 6, and being completely devoid of fabric. The boundary between uppermost continuous top layer 7 and impregnated fabric is indicated by a dashed line. The uppermost continuous top layer 7 has a top surface 8 with abrasive particles 9 embedded directly therein. The uppermost continuous top layer has, after having the abrasive particles embedded, a thickness D_i , measurable by ultrasound as outlined above. Embedding the abrasive particles 9 directly into the top surface 8 of the top layer 7 helps in reducing the overall thickness D_{tot} of the belt, which is favourable in view of its bendability over pulleys. This abrasive belt of the invention has an overall thickness D_{tot} of typically in the range of 1 to 3 mm, measurably by gauge as described above.

[0087] Fig. 7 is a schematic cross-sectional view of an abrasive pad or disk of the invention containing the fabric of the invention, along its longitudinal direction, cutting through the uncrimped warp filament 1 and the first and second uncrimped weft multifilaments, 301-308 and 309-316, respectively. It contains a fabric of the invention, an impregnation 6 and on one side of the impregnated fabric a first cover layer 71 of a thickness D_{i1} , consisting of the same impregnation material as the impregnation 6, but being completely devoid of fabric. In the shown embodiment there is also a second cover layer 72 of thickness D_{i2} , also consisting of the same impregnation material as the impregnation 6, but being completely devoid of fabric. This abrasive pad or belt contains first abrasive particles 91 in the form of a first prefabricated sheet 101 of thickness D_{i1}' and containing these first abrasive particles 91 embedded into its first top sheet surface 111. It may e.g. be an abrasive tape of type 262L, or a so-called "micro-finishing film" of type S, both produced by Minnesota Mining & Manufacturing. This first prefabricated sheet 101 has been laminated under heat and pressure, optionally with co-use of a compatible hotmelt adhesive (not shown) to the first top layer 71. A second prefabricated sheet 102, identical to the first prefabricated sheet 101 or different therefrom, of thickness D_{i2}' and containing further abrasive particles 92 (which may be same as the abrasive particles 91 or different therefrom) embedded into its second top sheet surface 112 has been laminated to the second top layer 72. This second prefabricated abrasive-containing layer is optional.

Claims

1. A woven fabric comprising:

- a) A first layer (A) of first uncrimped weft multifilaments (301-308) running essentially in parallel to each other and being spaced apart from each other by a distance D ;
 - b) a second layer (B) of second uncrimped weft multifilaments (309-316) running essentially in parallel to each other and being spaced apart from each other by said distance D ;
- wherein for each of the first uncrimped weft multifilaments (301-308) there is one corresponding second uncrimped weft multifilament (309-316), and vice versa, to form successive multifilament pairs (301/309, 302/310, 303/311, 304/312, 305/313, 306/314, 307/315, 308/316), each such successive multifilament pair being designatable with a unique and ascending integer index N ;
- c) crimped warp filaments (41-44) having one of the following weave types c1 - c4:

c1 - entwine around first uncrimped weft multifilaments (302, 306) of all multifilament pairs (302/310, 306/314) with indexes N fulfilling $(N \bmod 4) = 0$, such indexes N being designated as N_A ; pass between first (303, 307) and second (311, 315) uncrimped weft multifilaments of all multifilament pairs (303/311, 307/315) with indexes N fulfilling $(N \bmod 4) = 1$, such indexes N being designated as N_B ; entwine around second uncrimped weft multifilaments (312, 316) of all multifilament pairs (304/312, 308/316) with indexes N fulfilling $(N \bmod 4) = 2$, such indexes N being designated as N_C ; and pass between first (301, 305) and second (309, 313) uncrimped weft multifilaments of all multifilament pairs (301/309, 305/313) with indexes N fulfilling $(N \bmod 4) = 3$, such indexes N being designated as N_D ;

or

c2 - entwine around second uncrimped weft multifilaments (310, 314) of all multifilament pairs with said indexes N_A ; pass between first (303, 307) and second (311, 315) uncrimped weft multifilaments of all

multifilament pairs (303/311, 307/315) with said indexes N_B ; entwine around first uncrimped weft multifilaments (304, 308) of all multifilament pairs (304/312, 308/316) with said indexes N_C ; and pass between first and second uncrimped weft multifilaments of all multifilament pairs (301/309, 305/313) with said indexes N_D ;

or

c3 - pass between first (302, 306) and second (310, 314) uncrimped weft multifilaments of all multifilament pairs (302/310, 306/314) with said index N_A ; entwine around first uncrimped weft multifilaments (303, 307) of all multifilament pairs (303/311, 307/315) with said indexes N_B ; pass between first (304, 308) and second (312, 316) uncrimped weft multifilaments (304/312, 308/316) of all multifilament pairs with said indexes N_C ; and entwine around second uncrimped weft multifilaments (309, 313) of all multifilament pairs (301/309, 305/313) with said indexes N_D ;

or

c4 - pass between first (302, 306) and second (310, 314) uncrimped weft multifilaments of all multifilament pairs (302/310, 306/314) with said indexes N_A ; entwine around second uncrimped weft multifilaments (311, 315) of all multifilament pairs (303/311, 307/315) with said indexes N_B ; pass between first (304, 308) and second (312, 316) uncrimped weft multifilaments of all multifilament pairs (304/312, 308/316) with said indexes N_C ; and entwine around first uncrimped weft multifilaments (301, 305) of all multifilament pairs (301/309, 305/313) with said indexes N_D ;

d) uncrimped warp filaments (1) passing between first (301-308) and second (309-316) uncrimped weft multifilaments of all multifilament pairs (301/309, 302/310, 303/311, 304/312, 305/313, 306/314, 307/315, 308/316); and

e) optionally, crimped antistatic warp filaments having one of the weave types c1, c2, c3 or c4 defined above;

provided that crimped warp filaments (41-44) of all four above defined weave types c1, c2, c3 and c4 are present; wherein the fabric does not comprise any other crimped warp filaments, besides said crimped warp filaments (41-44) and said optional crimped antistatic warp filaments.

2. The fabric of claim 1, wherein each uncrimped warp filament (1) is separated in weft direction from the next uncrimped warp filament (1) by an even number of crimped warp filaments (41-44), said even number being at least 2.
3. The fabric of claim 1 or 2, wherein each uncrimped warp filament (1) is sandwiched in weft direction by two immediately adjacent crimped warp filaments (42,43).
4. The fabric of one of claims 1 to 3, wherein the crimped warp filaments of weave types c1 (41) and c2 (42) defined in claim 1 are always present pairwise and immediately adjacent to each other in weft direction, and the crimped warp filaments of weave types c3 (43) and c4 (44) defined in claim 1 are always present pairwise and immediately adjacent to each other in weft direction.
5. The fabric of one of claims 1 to 4, wherein the numerical ratio of crimped warp filaments c) (41-44) to uncrimped warp filaments d) (1) is in the range of 4:1 to 12:1.
6. The fabric of one of claims 1 to 5, wherein the crimped warp filaments c) (41, 42, 43, 44) and the uncrimped warp filaments d) (4) are arranged in repetitive units in weft direction, in which repetitive units the order in which the uncrimped warp filaments d) (1) and the crimped warp filaments of above weave types c1 (41), c2 (42), c3 (43) and c4 (44) are arranged in weft direction is always the same.
7. The fabric of one of claims 1 to 6, comprising the crimped antistatic warp filaments e).
8. The fabric of one of claims 1 to 7, consisting of first uncrimped weft multifilaments a) (301-308), second uncrimped weft multifilaments b) (309-316), crimped warp filaments c) (41-44), uncrimped warp filaments d) (1) and optional crimped antistatic warp filaments e).
9. An abrasive product comprising
 - i) a fabric according to any one of claims 1 to 8 which is impregnated with an impregnation (6) comprising or consisting of a thermoplastic, thermoplastic elastomer, thermoset, elastomer or mixture thereof;
 - ii) immediately adjoining to one side of the impregnated fabric a first top layer (7) with a first topmost surface (8) comprising or consisting of the same thermoplastic, thermoplastic elastomer, thermoset, elastomer or mixture

thereof as in the impregnation (6) in the fabric but being devoid of fabric, and
iii) a first particulate abrasive material (9) embedded into the first topmost surface (8) of the first top layer (7).

5 10. The abrasive product of claim 9, which is an endless abrasive belt.

11. The abrasive product of claim 9, furthermore comprising:

10 iv) immediately adjoining to the other side of the impregnated fabric a second top layer with a second topmost surface and being made of the same thermoplastic, thermoplastic elastomer, thermoset, elastomer or mixture thereof as in the impregnation (6) in the fabric but being devoid of fabric; and
v) a second particulate abrasive material embedded into the second topmost surface of the second top layer.

12. An abrasive product comprising:

15 i) a fabric according to any one of claims 1 to 8 which is impregnated with an impregnation (6) comprising or consisting of a thermoplastic, thermoplastic elastomer, thermoset, elastomer or mixture thereof;
ii) optionally, immediately adjoining to one side of the impregnated fabric, a first cover layer (71) comprising or consisting of the same thermoplastic, thermoplastic elastomer, thermoset, elastomer or mixture thereof as in
20 the impregnation (6) in the fabric but being devoid of fabric;
iii) adjoining to said one side of the impregnated fabric, or, if the first cover layer (71) is present, to said first cover layer (71) a first prefabricated abrasive sheet (101) with a first top sheet surface (111) containing first abrasive particles (91) embedded into the first top sheet surface (111).

25 13. The abrasive product of claim 12, furthermore comprising:

iv) optionally, immediately adjoining to the other side of the impregnated fabric, a second cover layer (72) comprising or consisting of the same thermoplastic, thermoplastic elastomer, thermoset, elastomer or mixture thereof as in the impregnation (6) in the fabric but being devoid of fabric;
iv) adjoining to said other side of the impregnated fabric, or, if the second cover layer (72) is present, to said
30 second cover layer (72), a second prefabricated abrasive sheet (102) with a second top sheet surface (112) containing second abrasive particles (92) embedded into the second top sheet surface (112).

14. The abrasive product of claim 12 or 13, which is an abrasive pad or abrasive disk.

35 15. The abrasive product of one of claims 11 to 14, wherein the impregnation (6) is of a thermoplastic or thermoplastic elastomer, in particular a TPU.

40

45

50

55

Fig. 1

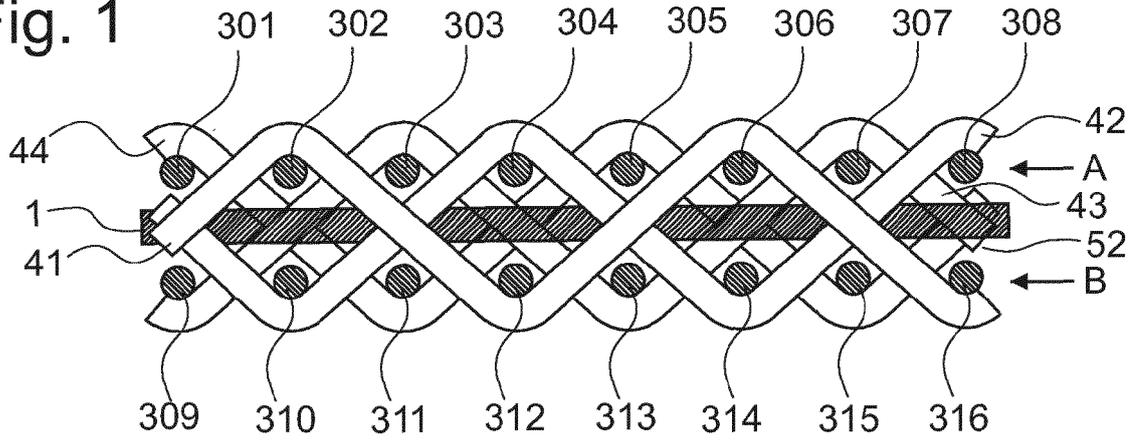


Fig. 2

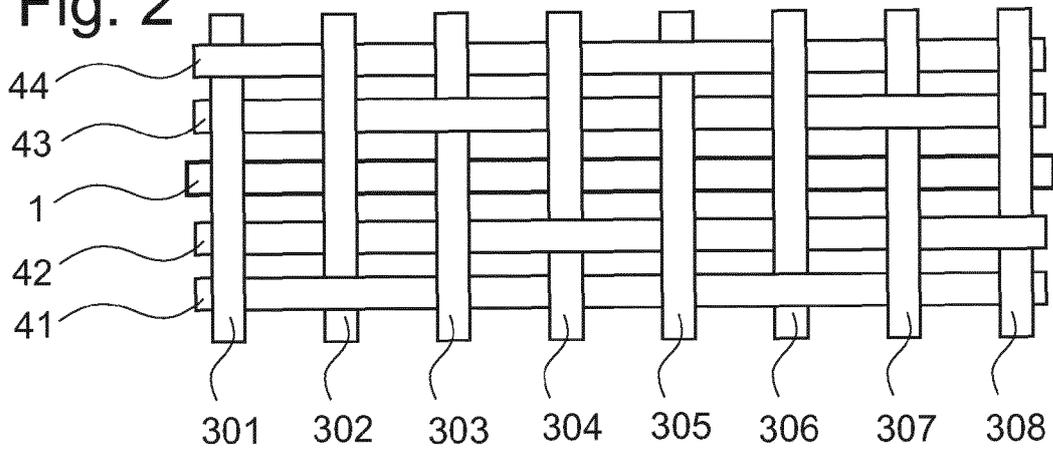


Fig. 3

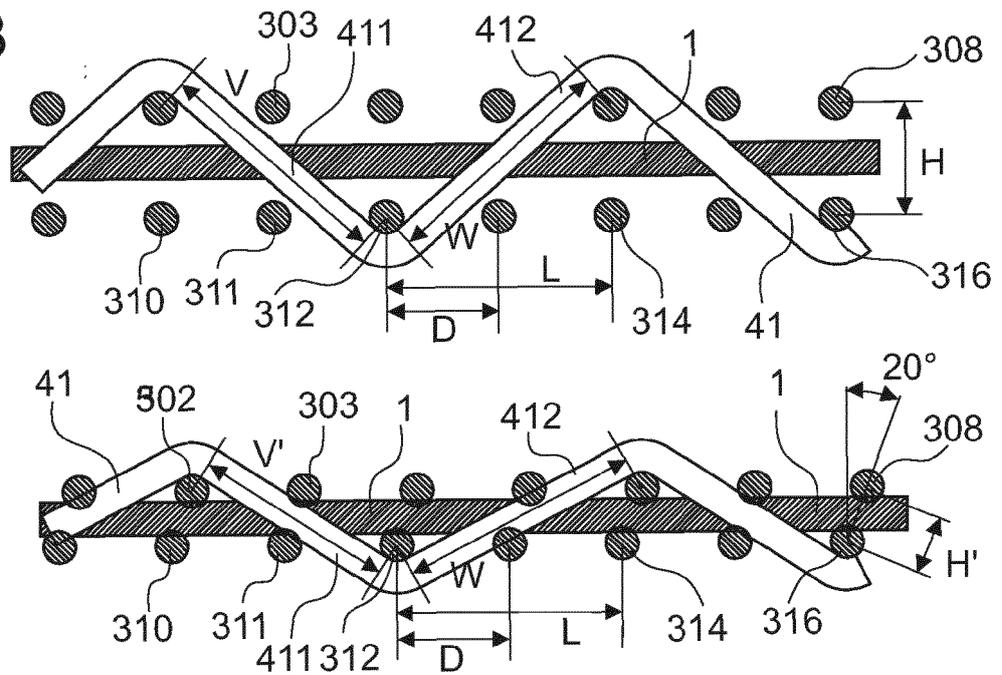


Fig. 4

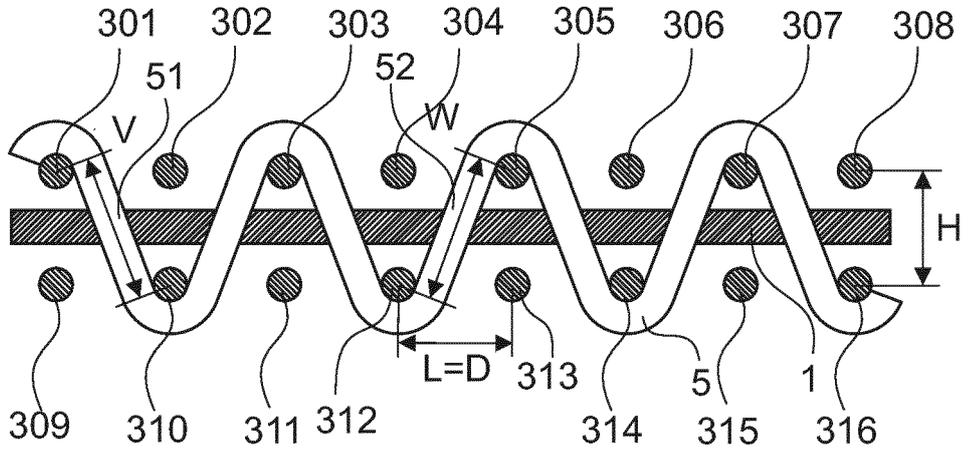


Fig. 5

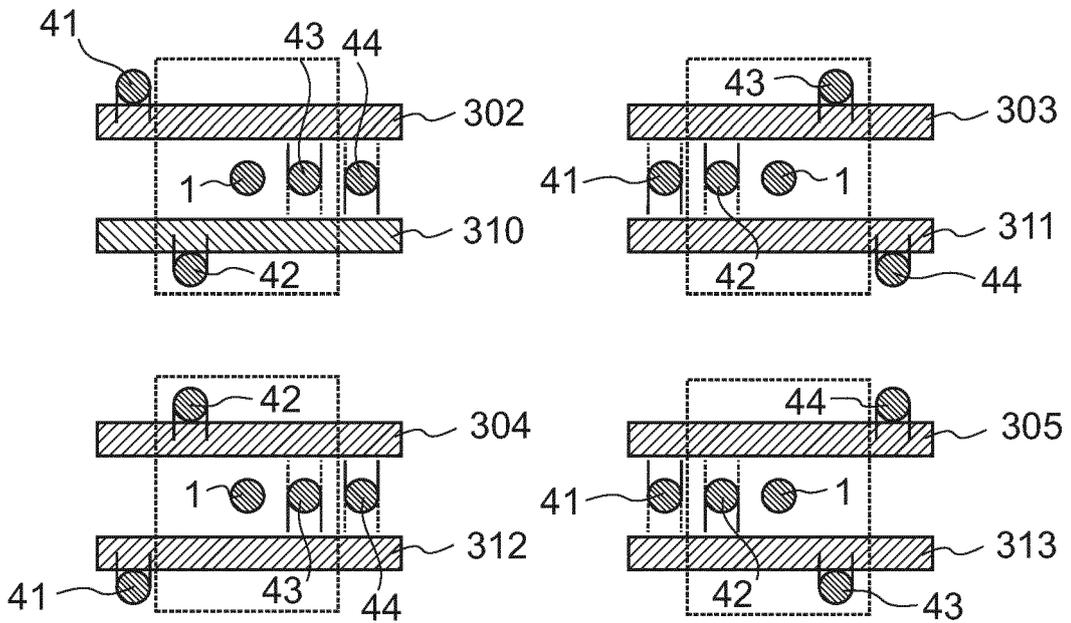


Fig. 6

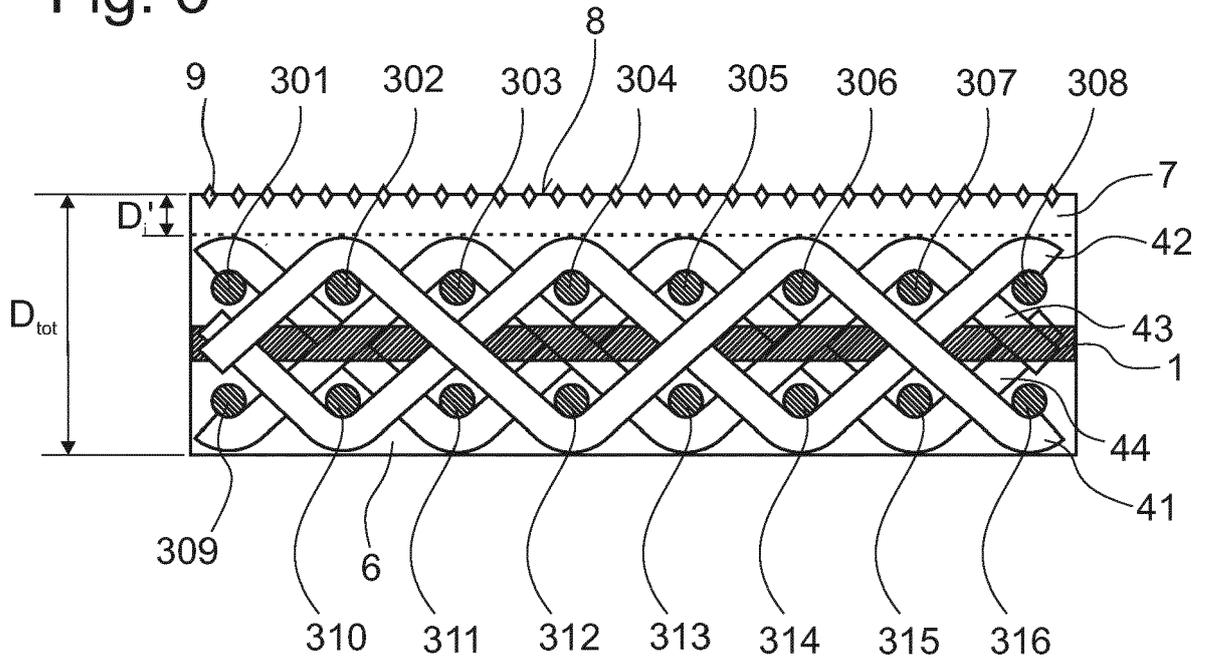
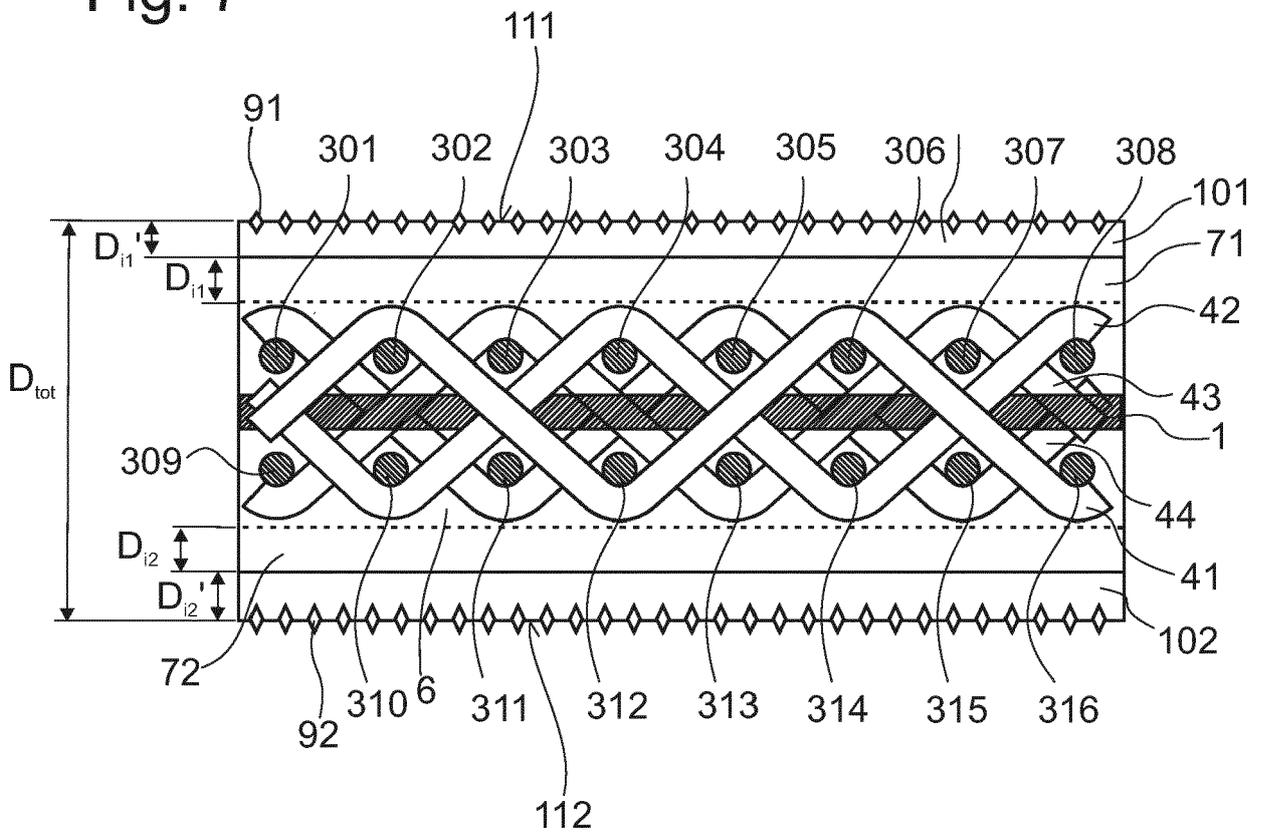


Fig. 7





EUROPEAN SEARCH REPORT

Application Number
EP 18 16 4287

5

10

15

20

25

30

35

40

45

50

55

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|--|---|--|---|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
| X | JP 2002 068440 A (NIPPON JIIKURINGU KK) 8 March 2002 (2002-03-08) * abstract * * claims 1-6 * * figures 1-3,5-7 * * paragraphs [0001], [0002], [0004] - [0011], [0013], [0018], [0020], [0021], [0022], [0024] - [0026], [0029], [0030] * ----- | 1-8 | INV. D03D11/00 B24D11/00 |
| X | GB 562 611 A (CARBORUNDUM CO) 10 July 1944 (1944-07-10) * claims 1-11 * * figures 1,2 * * page 1, line 1 - line 93 * * page 2, line 115 - line 123 * * page 3, line 50 - line 100 * ----- | 1,9-14 15 | TECHNICAL FIELDS SEARCHED (IPC) D03D B24D |
| Y | GB 1 390 603 A (BBA GROUP LTD) 16 April 1975 (1975-04-16) * claims 1-4,6,10 * * figures 1,3,4 * * page 1 - page 3 * ----- | 15 | |
| Y,D | | | |
| The present search report has been drawn up for all claims | | | |
| Place of search Munich | | Date of completion of the search 6 July 2018 | Examiner Heinzelmann, Eric |
| 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 | | | |

EPO FORM 1503 03.02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 18 16 4287

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

06-07-2018

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---------------------|----------------------------|---------------------|
| JP 2002068440 A | 08-03-2002 | NONE | |
| GB 562611 A | 10-07-1944 | NONE | |
| GB 1390603 A | 16-04-1975 | NONE | |

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2013240839 A [0005]
- JP 2011093083 A [0006]
- WO 2012042040 A [0007]
- US 20100323574 A [0008]
- GB 1390603 A [0009]
- US 2992150 A [0017]

Non-patent literature cited in the description

- Acoustic properties of polymers. **JAMES E. MARK.**
Physical Properties of Polymers Handbook [0047]