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(54) STRAP WITH FAILURE INDICATOR AND SAFETY DEVICE INCLUDING THE SAME

(57) The invention relates to a strap with a failure indicator and a safety device including the strap. The strap comprises: a main body structure (10) formed by knitting; and one or more second yarns (12) integrated straight into the main body structure (10) in the length direction of the main body structure (10) along the entire length of the main body structure (10) and at least partially fixed to the main body structure (10); wherein the main body structure (10) and the second yarn (12) are selected such that the main body structure (10) and the second yarn (12) are elongated and do not break under a predetermined amount of a tensile force, and after the tensile force is released, the main body structure (10) retracts, such that at least one second yarn (12) at least partially protrudes from a plane of the main body structure (10) to form a failure indicating loop. The safety device according to the invention comprises a component formed by the strap with a failure indicator. The invention also relates to a method for manufacturing a strap with a failure indicator.

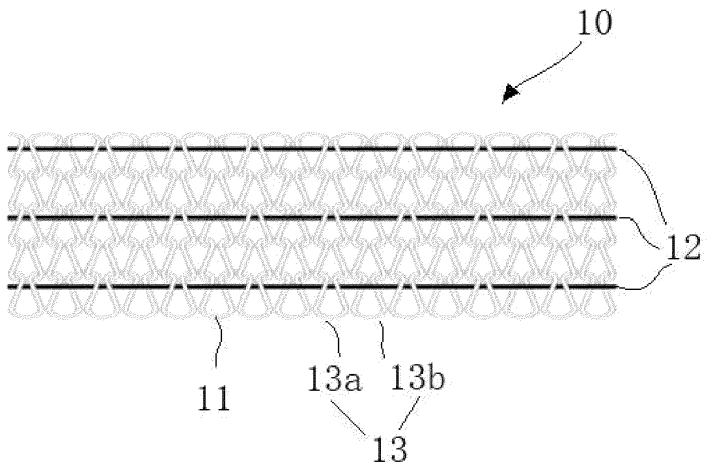

Fig. 1B

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Description

Technical Field

[0001] The present invention relates to a strap with a failure indicator and a safety device including the strap, such as a safety harness, a safety rope, a safety helmet including a suspension system formed by the strap, etc.

Background

[0002] Existing safety devices on the market, such as safety helmets, have a smart damage indicator that may provide a visual indication of age/wear/damage using a sensor and an additional circuitry or a battery and a light. For example, US20070056081A1 discloses a safety helmet, wherein in order to allow monitoring of the occurrence of impacts, an impact sensor in the form of a layer 18 of a material sensitive to the occurrence of such impacts is provided to the helmet, wherein the layer 18 has the quality that its electrical resistance varies as the mechanical load applied thereto varies. The electrical resistance across the layer 18 is, under normal circumstances, high. However, in the event of an impact resulting from, for example, the wearer being involved in a road traffic accident and his head impacting upon the road surface or another hard object, the impact force will temporarily squash or compress the layer 18 thus causing a temporary reduction in the electrical resistance across the layer 18. Correspondingly, a unit 22 including an internal power source in the form of, for example, a battery, and a memory is provided to monitor the electrical resistance across the layer 18. A warning device 24, for example an LED, sends a warning in the event of the occurrence of an impact. Obviously, where a warning light is used, there is the risk that if the battery runs flat, no warning signal will be produced. And the use of electronics increases the cost of the safety helmet.

[0003] Therefore, an improved solution is needed that does not use batteries or electronics and can reliably indicate whether damage has occurred.

Summary of the Invention

[0004] The present invention has been made in view of the above problems in the prior art.

[0005] One of objects of the invention is to provide a strap with a failure indicator to indicate whether stretching, impact, or damage has occurred. The strap comprises: a main body structure formed by knitting; and one or more second yarns integrated straight into the main body structure in a length direction of the main body structure along the entire length of the main body structure and at least partially fixed to the main body structure; wherein the main body structure and the second yarn are selected such that the main body structure and the second yarn are elongated and do not break under a predetermined amount of a tensile force, and after the tensile force is released, the main body structure retracts, such that at least one second yarn at least partially protrudes from a plane of the main body structure to form a failure indicating loop.

[0006] Preferably, under the predetermined amount of the tensile force, the elongated length of the main body structure is greater than that of the second yarn, such that the second yarn detaches from the fixation to the main body structure and can slide in the main body structure (i.e., slide relative to the main body structure); when the tensile force is released, the main body structure retracts, and the second yarn does not retract due to occurred plastic deformation, such that the length of the main body structure is shorter than the length of at least one second yarn that has slid, thereby the at least one second yarn at least partially protruding from the plane of the main body structure.

[0007] Further preferably, the strap has a compensating portion, which can compensate for the difference in elongated lengths between the main body structure and the second yarn under the predetermined amount of the tensile force, i.e., the compensating portion can be used to limit the elongated length of the main body structure. Preferably, the compensating portion is formed by setting the second yarn to be longer than the main body structure; more preferably, the part of the second yarn that is longer than the main body structure is folded along a width direction of the main body structure and fixed to the main body structure by, for example, a hot melt glue. Yet preferably, the compensating portion is formed by folding an end of the main body structure.

[0008] Preferably, the main body structure is formed by knitting a first yarn, which is different from the second yarn, in the manner of plain weave, double-sided weave, jacquard weave, etc., such that the maximum tensile force of a single main body structure is in the range of 800~2000 N, and the elongation is approximately in the range of 15%~35%. Preferably, the material of the first yarn may be selected from elastic retractable materials, such as polyester low-elastic yarn, polyester high-elastic yarn, and spandex core-spun material and the like. The material of the first yarn may also be selected from materials that cannot retract after stretching, such as polyester, polyamide, natural fiber (cotton, linen, silk and wool), and other man-made fibers, such as viscose fiber, acrylic fiber, acetate fiber, etc. Preferably, after the tensile force is released, the main body structure retracts to its original length, and the first yarn may be made of, for example, polyester low-elastic yarn, polyester high-elastic yarn, spandex core-spun material or the like. The retracting property of the loops knitted from the first yarn after stretching relies mainly on the loop structure itself and the properties of the material of the first yarn itself. If the material of the first yarn itself has little or no elastic retraction, the strap can still retract due to the loop structure.

[0009] Preferably, the material of the second yarn has a tensile strength approximately at least 2.0 N/tex and an

elongation at break approximately in the range of 2~5%. The second material may be selected from ultra-high molecular weight polyethylene (UHMWP), liquid crystal polymer (LCP), para-aramid or any suitable material.

[0010] Preferably, under a predetermined amount of a tensile force, the second yarn deforms synchronously with the main body structure, and after the tensile force is released, the length of the main body structure after retraction is smaller than the length of at least one second yarn that has deformed plastically, such that the at least one second yarn at least partially protrudes from the plane of the main body structure to form a failure indicating loop. Preferably, the main body structure is elongated due to the deformation of the orientation of knitted loops of the main body structure as well as the straightening of the arcs of the knitted loops, and the main body structure can fully recover from being elongated. The second yarn is elongated due to plastic deformation. Preferably, the material of the second yarn may be MDPE or HDPE yarn or PE yarn. For example, PE yarn has a strength of 2.6-4.2 g/D, and its elongation at break can reach 65%.

[0011] Preferably, integrating the second yarn straight into the main body structure is embodied by inlaying a plurality of second yarns straight in the knitted loops of the main body structure, or by knitting a plurality of second yarns straight into the knitted loops of the main body structure in plain stitch. Preferably, the plurality of second yarns is formed by a single second yarn which is in a serpentine arrangement and turns at the end of the main body structure. Preferably, the second yarn is arranged symmetrically with respect to a longitudinal central axis of the main body structure.

[0012] Preferably, the fixation of the second yarn to the main body structure is realized by winding a thermal fuse around the at least one second yarn with a twist of 6~10 turns/cm and fixing the at least one second yarn into the main structure by heat treatment setting, or by using an adhesive. The second yarn may be twisted to enhance the strength, or untwisted.

[0013] Another object of the invention is to provide a safety device, which comprises a component formed by the above-mentioned strap with a failure indicator, to facilitate determining whether the safety device has been damaged.

[0014] Preferably, the safety device is a safety helmet and the component is a suspension system. The suspension system is provided in a helmet body of the safety helmet and a cushion pad of the suspension system is spaced apart from the helmet body. The suspension system comprises a plurality of straps symmetrically connected to the cushion pad, and at least one of the plurality of straps is formed by the above-mentioned strap with a failure indicator. Preferably, a total length of the compensating portion is selected to not exceed the vertical distance between the cushion pad and the helmet body. Preferably, the multiple straps may be two straps fixed in the helmet body at 4 or 8 points, or three straps fixed in the helmet body at 6, 8 or 12 points. In the case of three straps, at least one strap has a different length or structure from other straps.

[0015] Preferably, the safety device may be a safety harness or a safety rope worn on a person.

[0016] Yet another object of the invention is to provide a method for manufacturing a strap with a failure indicator, comprising:

a) providing a first yarn;
b) providing a second yarn;
c) knitting the first yarn to form a main body structure, and integrating the second yarn straight into the main body structure and extending the entire length of the main body structure, and
d) at least partially fixing the second yarn to the main body structure;

wherein the main body structure and the second yarn are selected such that the main body structure and the second yarn are elongated and do not break under a predetermined amount of a tensile force, and after the tensile force is released, the main body structure retracts, such that at least one second yarn can at least partially protrude from a plane of the main body structure to form a failure indicating loop.

[0017] Preferably, in step c, knitting the first yarn in a manner of plain weave, double-sided weave, jacquard weave, etc., to form the main body structure, such that the main body structure is elongated under the predetermined amount of the tensile force substantially due to the deformation of the orientation of knitted loops and the straightening of the arcs of the knitted loops.

[0018] Preferably, the method further comprises: in step b, winding a thermal fuse on the second yarn, the twist of the thermal fuse being further preferably 6~10 turns/cm; and in step d, heating the strap to melt the thermal fuse to fix the second yarn to the main body structure. The melting point of the thermal fuse is 80~130°C. Therefore, heating the strap is carried out by applying to the strap a temperature higher than the melting point of the thermal fuse.

[0019] Additional applicable areas of this disclosure will become apparent in the light of the detailed description, claims and drawings. The detailed descriptions and specific examples are intended for illustrative purposes only and are not intended to limit the scope of this disclosure.

Brief Description of the Drawings

[0020] The preferred embodiments of the invention will be explained in more detail below in conjunction with the accompanying drawings to better understand the features and advantages of the invention. The embodiments of the invention will now be further described with reference to the accompanying drawings, in which:

FIG. 1A schematically shows a first strap with a

failure indicator according to a first embodiment of the invention;

FIG. 1B schematically shows a partial enlarged view of the strap of FIG. 1A;

FIG. 2A schematically shows a first strap structure made of the strap of FIG. 1A, in which each end of the strap is folded twice and fixed together by a suture, and the strap has not been subjected to any tensile force;

FIG. 2B schematically shows the state of the first strap structure in FIG. 2A after it has been subjected to a tensile force;

FIG. 3 schematically shows a second strap with a failure indicator according to a second embodiment of the invention;

FIG. 4A schematically shows a second strap structure made of the strap of FIG. 3, in which each end of the strap is folded once and is fixed together by a suture, and the strap has not been subjected to any tensile force;

FIG. 4B schematically shows the state of the second strap structure in FIG. 4A after it has been subjected to a tensile force;

FIG. 5A schematically shows part of a third strap with a failure indicator according to a third embodiment of the invention, wherein the strap has not been subjected to any tensile force;

FIG. 5B schematically shows the state of the strap in FIG. 5A after it has been subjected to a tensile force;

FIG. 6 schematically shows an exemplary arrangement of the failure indicator according to the invention in the strap; and

FIG. 7 schematically shows the knitting process of the strap according to the invention.

[0021] In the drawings, components with the same function have the same or similar reference signs, unless specified otherwise. It will be understood that the figures are not drawn to scale, and are only intended to schematically best illustrate the structures.

Detailed Description of the Invention

[0022] The invention will be described in more detail below with reference to exemplary embodiments. The following embodiments are intended to illustrate the invention by example, and it should be clear to those skilled in the art that the invention is not limited to these embodiments or experimental data. It should be understood that equivalent functions and structures can be embodied by different implementations, which are also intended to be contained within the spirit and scope of this disclosure.

[0023] FIG. 1A shows a strap with a failure indicator according to the first embodiment of the invention. The length of the strap is 340 ± 5 mm, and the width is 20 ± 2 mm. The strap comprises a reinforced part of 100 mm that is substantially centered along a length direction, and the thickness of the strap is 1.5 ± 0.2 mm in the unreinforced part and 2.2 ± 0.2 mm in the reinforced part, wherein the reinforced part of the strap is realized by knitting into double layers. Alternatively, the reinforced part may also be implemented by other means known to those skilled in the art, and the length, width and thickness of the strap and the reinforced part may be selected according to actual needs to provide a better cushioning effect.

[0024] FIG. 1B schematically shows a partial enlarged view of Part A of the knitted structure of the strap of FIG. 1A. The knitted structure comprises a main body structure 10 and three second yarns 12 inlaid straight in the main body structure in the length direction of the main body structure along the entire length of the main body structure. The second yarns 12 are fixed to the main body structure in a at least partially releasable manner, for example fixed at an end area of the strap. The main body structure 10 is plain woven from a first yarn 11, and comprises a plurality of intermeshing loops 13 formed by the first yarn 11. The plurality of intermeshing loops 13 defines a plurality of horizontal transverse rows and vertical longitudinal rows. The second yarns 12 are arranged straight in the alternate transverse rows and each alternates, in a respective transverse row, between being (i) behind the loop 13a formed by the first yarn 11 and (ii) in front of the loop 13b formed by the first yarn 11. The strap shown in FIG. 1A includes six second yarns, which are arranged symmetrically in groups of three relative to the longitudinal central axis of the strap to promote uniform force distribution. Preferably, although the first yarn 11 forms each of the transverse rows in this configuration, additional yarns of different materials may form one or more of the transverse rows or may form part of one or more of the transverse rows, so as to, for example, provide a reinforced part.

[0025] The fixation of the second yarn 12 to the main body structure can be realized as follows: a thermal fuse with a twist of about 6~10 turns/cm is wound on the second yarn 12 locally or along the entire length, and the thermal fuse is melted by heating, such that the second yarn and the loop 13 are fixed together at overlapping portions. If the twist of the thermal fuse is too small, a firm fixation cannot be achieved. If the twist is too large (i.e., too much winding), the knitted strap would feel hard, and it may also cause that under an instantaneous load, the second yarn cannot be separated from the main body structure due to a too firm bond, and thus cannot slide or be elongated, losing its indicating function. The thermal fuse may be a low melting point thermal fuse, for example, the nylon thermal fuse with specifications of 100 D (D: denier), 150 D, and 180 D sold by Fujian YiMing Thread Co, Ltd. Alternatively, in the absence of a thermal fuse, a releasable fixation of the second yarn 12 to the main body structure may be achieved by any suitable means, e.g. by means of an adhesive.

[0026] In the strap of FIG. 1A, the first yarn 11 is a polyester fiber core-spun spandex yarn, and the main body structure is plain woven from this yarn and can reach an elongation of 25%~30%. A 1000 D LCP of a

primary color is used as the second yarn 12 which serves as a failure indicator, 1000 D LCP has a tensile strength of 2.1 N/dtex and an elongation at break of about 3.4%. The melted thermal fuse (not shown) is a transparent 150 D nylon thermal fuse wound on the second yarn along the length of the second yarn with a twist of about 8 turns/cm. When the strap in FIG. 1A is subjected to a predetermined amount of a tensile force, both the main body structure and the LCP yarn can be elongated without failing. However, since the elongated length of the LCP yarn is shorter, the LCP yarn which is at least partially fixed to the main body structure of the strap will detach from the main body structure and slide in the main body structure during stretching the strap, such that after the tensile force is released, the main body structure retract to approximately the original length and the second yarn do not retract, whereby the second yarn protrudes at least partially from the plane of the main body structure due to friction to form a failure indicating loop. The second yarn may have a different color from the main body structure to make the protruded indicating loop clearly evident, whereby the second yarn can be easily used as an indicator of whether the strap has undergone stretching.

[0027] In another embodiment, the second yarn is set to be longer than the main body structure, and the part that is longer than the main body structure is folded in a width direction of the main body structure (if much longer, it may need to be folded several times) or folded in the length direction, and fixed to the main body structure at several points by, for example, a hot melt glue. In this way, under a predetermined amount of a tensile force, since the second yarn has a different strain rate from that of the main body structure, the second yarn will detach completely from the fixation to the main body structure by overcoming the fixing force of the thermal fuse, such that the second yarn can slide relative to the main body structure during elongating the main body structure. After the predetermined amount of the tensile force is released, the second yarn would be longer than the main body structure due to the retraction of the main body structure, and would thus protrude from the plane of the main body structure, forming a failure indicating loop.

[0028] A mechanical test is performed on the strap using an INSTRON 5967 test machine in accordance with the ISO 13934 standard, wherein standard distance is 220 mm, the reinforced part of the strap is centered, tensile rate is 100 mm/min, test temperature is 26±3°C, and humidity is 85%. As a result, the maximum tensile load of the strap is not less than 800 N, and the strap is extended by 62 ± 5 mm at the maximum tensile load, i.e., the elongation is about 28%.

[0029] FIG. 2A schematically shows the state of a first strap structure made by the strap according to FIG. 1A before it is subjected to any tensile force. The strap structure can be used, for example, in the suspension system of a safety helmet, wherein the second yarns are securely fixed at the ends of the main body structure. The first strap structure comprises a first section 14 and a first bending portion 16 and a second bending portion (hereinafter referred to as a compensating portion 17) sequentially formed at each end of the first section, wherein the first bending portion and the compensating portion are formed in the following manner: each end of the strap is folded twice in opposite directions to respectively form a two-layer structure connected directly to the first section, i.e., a first bending portion, and a two-layer structure connected directly to the first bending portion, i.e., a compensating portion 17. The main body part of the end of the strap is fixed by, for example, a suture 15 to the first bending portion and the main body structure of the first section adjacent to the first bending portion. This fixation does not affect the subsequent sliding of the second yarn. The suture 15 is the boundary between the first section and the first bending portion, and also the boundary between the first bending portion and the compensating portion. The length L of the first strap structure is about 280 mm, and each compensating portion 17 is about 20 mm long when unfolded, that is, the total length of the compensating portions 17 is 40 mm when unfolded.

[0030] In order to determine the indicating function of the strap, a top impact test can be carried out on a safety helmet with a suspension system formed by the strap according to the DIN EN 397, ANSI Z89.1 Type 1 & Type II or EN 12492:2012 standards. For example, the DIN EN 397 or EN 12492:2012 standards mainly includes putting the safety helmet on a headform and allowing a 5 kg semi-spherical metal hammer with a diameter of 50 mm to fall freely from a height of 1 m or 2 m, respectively, to hit the centre on the top of the helmet (which would cause a predetermined amount of a tensile force). The test is completed within 1 minute. The ANSI Z89.1 standard uses a 3.6 kg hammer to strike the center on the top of the helmet in free fall from a height of 1.5 m. It will be understood that this predetermined amount of the tensile force can also be, for example, a specific value selected according to other suitable standards or other actual needs. The following is only illustrated using EN 12492:2012 as an example.

[0031] As shown in FIG. 2B, after experiencing an impact load according to the EN 12492:2012 standard, the entire first strap structure retracts to its original length, whereas the second yarns 12 partially protrude from the plane of the main body structure to form failure indicating loops. Due to the color difference between the second yarn and the main body structure, the protruded loops are particularly noticeable, making it possible to visually check these protruded loops to determine that the strap and thus the safety helmet have experienced an impact and can no longer be used. In addition, the compensating portion 17 is curled up and presents a distinctly thickened portion, which also indicates that the strap has been stretched.

[0032] The reasons why the second yarn 12 can be used as a failure indicator are explained as follows.

[0033] Under a predetermined amount of a tensile

force (as mentioned above, the tensile force generated by hitting the center on the top of the helmet by the free fall of a 5 kg semi-spherical metal hammer with a diameter of 50 mm from a height of 2 meters), the main body structure knitted from the core-spun spandex yarn and the 1000 D LCP yarns inlaid straight in the main body structure both can be extended without failing, thereby achieving the effect of relieving an instantaneous impact force. In this process, the main body structure is elongated due to the deformation of the orientation of its knitted loops and the straightening of the arcs of the knitted loops. Therefore, the main body structure can easily restore to its original length after the tensile force is released. In contrast, since the strain rate of the second yarn is different from that of the main body structure, the plurality of second yarns are completely detached from the main body structure by overcoming the fixing force of the thermal fuse except at the end of the strap, such that the second yarns can slide relative to the main body structure during elongating the main body structure. In this case, since the extension degree of the second yarn is smaller than that of the main body structure, the second yarn in the compensating portion 17 is tightened (i.e., slides to the first bending portion and the first section relative to the main body structure of the compensating portion 17) to make up for the difference in elongated lengths between the second yarn and the main body structure, thereby causing the compensating portion 17 to curl up. After the tensile force is released, due to the plastic deformation that occurs in the second yarn, preventing it from retracting completely, the final length of the main body structure would be shorter than the length of at least one second yarn 12, whereby the second yarn 12 at least partially protrude from the plane of the main body structure and form failure indicating loops. At the same time, most of the compensating portion 17 that has curled up cannot be unfolded because the second yarn does not retract, so the compensating portion 17 can also be used as a failure indicator. It is worth noting that during the stretching process, most of the second yarn, which is with high strength and low elongation, in the compensating portion 17 is drawn to the first bending portion and the first section, thereby making up for the difference in elongated lengths between the second yarn and the main body structure. As shown in the present embodiment, the maximum elongated length that can be compensated is about 40 mm. Considering that the elongated length of the second yarn is extremely small, it can be said that the compensating portions can limit the elongated length of the main body structure to about 40 mm. Accordingly, the length of the compensating portions can be designed as needed, for example, to ensure that the cushion pad of the suspension system of the safety helmet under impact does not contact the helmet body, so as to improve the safety of the helmet.

[0034] FIG. 3 schematically shows a second strap according to a second embodiment of the invention, which is constructed in a manner similar to that of the first embodiment, except that the second yarn is formed by a single second yarn 22 in a serpentine arrangement. In the serpentine arrangement, starting from the right end of the main body structure 20 of the second strap, a first inlaid part of the single second yarn extends the entire length of the main body structure and turns at the left end of the main body structure to form a second inlaid part extending the entire length of the main body structure, which turns again at the right end of the main body structure to form a third inlaid part and so on until six inlaid parts are formed. The second yarn is at least partially fixed to the main body structure by means of glue or hot melt glue. It will be understood that the single second yarn can form more or fewer straight inlaid parts, such as 8, 10, 12, etc.

[0035] Similar to FIG. 2A, FIG. 4A schematically shows the state of a second strap structure formed by the second strap in FIG. 3 before it is subjected to any tensile force. The first yarn 21 of the second strap structure is an inelastic yarn, for example, 600 D polyester dyed into steel grey with a tensile strength of 3.52 cN/dtex. The main body structure is plain woven from this first yarn and can reach an elongation of 25%-30%, and the second yarn 22 is formed by LCP. The second strap structure comprises a first section 24, and a first bending portion 26 and a compensating portion 27 at both ends of the first section 24. The first bending portion 26 and the compensating portion 27 are fixed by a suture 25 which also serves as a boundary therebetween. The second strap structure has a length L of 255 $\pm$ 5 mm, a width of 20 $\pm$ 2 mm, and a double-layered reinforced part of 100 mm that is substantially centered along a length direction, a thickness of 1.5 $\pm$ 0.2 mm in the unreinforced part and 2.2 $\pm$ 0.2 mm in the reinforced part.

[0036] As shown in FIG. 4B, after experiencing a tensile force according to the EN 12492:2012 standard, the second strap structure is about 275 mm $\pm$ 5 mm in length. The second strap structure retracts but not to its original length, and is in an elongated state. This is because the first yarn 21 is an inelastic yarn, so it also undergoes plastic deformation during the stretching process. As a result, after releasing the predetermined amount of the tensile force, the main body structure still has a certain deformation elongated length after retraction (caused by the loops returning to their original state). At the same time, during the stretching process, the second yarn 22 is completely detached from the fixation to the main body structure because it does not match the elongated speed of the main body structure, such that the second yarn 22 can slide in the main body structure. Since the single second yarn 21 is serpentinely arranged, the part of the second yarn that is initially in the compensating portion 27 slides towards the first bending portion and the first section 24 (i.e., tightens in the compensating portion), causing the compensating portion to curl up. After the tensile force is released, the second yarn which cannot retract would at least partially protrude from the plane of the partially retracted main body structure to form loops,

indicating that the strap structure has undergone stretching. At the same time, most of the compensating portion 17, which has curled up, is unable to unfold because the second yarn does not retract, and thus can also indicate that the strap structure has undergone stretching.

[0037] Alternatively, the main body structure can be obtained by knitting the first yarn in the manner of double-sided weave, jacquard weave, etc. Preferably, in each embodiment mentioned above, the first material used for the first yarn may be an elastic yarn so as to retract the main body structure to its original length after a predetermined amount of a tensile force is released, and may be selected from materials as follows: polyester low-elastic yarn, polyester high-elastic yarn, spandex core-spun material, etc. In addition, the first material may also be non-elastic yarn, that is, materials that cannot retract after stretching, such as polyester, polyamide, natural fiber (cotton, linen, silk and wool), and other man-made fibers, such as viscose fiber, acrylic fiber, acetate fiber, etc. Due to the yarns of these materials are plastically elongated, the main body structure knitted from them still has a certain deformation elongated length after retraction (caused by the return of the loops to their original shape).

[0038] Correspondingly, the second yarn 12, 22 inlaid in the main body structure has a tensile strength higher than 2 N/tex and a low elongation at break between 2-5%, compared to the main body structure. The secondary material used for the second yarn 12, 22 is ultra-high molecular weight polyethylene (UHMWP), liquid crystal polymer (LCP) or any suitable material. For example, 1000D LCP yarn has a tensile strength of about 2.1 N/tex and an elongation at break of about 3.4%. For example, UHMWP yarn has a tensile strength of about 3.3 N/tex and an elongation at break of about 4%. For example, para-aramid yarn has a tensile strength of 2.08 N/tex and an elongation at break of about 2.4%.

[0039] FIGS. 5A and FIG. 5B schematically show the state of a third strap according to the invention before receiving any tensile force and after experiencing a tensile force according to the EN 12492:2012 standard, respectively. As shown in FIG. 5A, similar to the first embodiment, the main body structure 30 of the third strap is knitted from the first yarn, so no specific knitted manner is shown. A plurality of second yarns 32 are knitted straight into the main body structure in plain stitch such that the second yarns 32 are flush with the main body structure and at least partially fixed to the main body structure. In the process of experiencing the tensile force, the main body structure and the second yarn are synchronously deformed, that is, have the same elongated length, wherein the deformation of the main body structure is mainly due to the elongated length resulting from the deformation of the orientation of its knitted loops and the straightening of the arcs of the knitted loops, and a possible deformation elongated length resulting from the deformation of the first yarn, whereas the straight second yarns are deformed plastically due to its own extension. Therefore, after the tensile force is released, the main body structure can easily return to its original length or only has a deformation elongated length caused by the deformation of the first yarn. However, the second yarns cannot return to their original lengths, and thus become longer than the main body structure and can protrude from the plane of the main body structure to form failure indicating loops so as to judge the usability of the strap, as shown schematically in FIG. 5B.

[0040] Preferably, the material of the first yarn of the main body structure 30 may be the same as that of the first yarns of the preceding embodiments. The difference lies in that, since the second yarn 32 can be deformed synchronously with the main body structure 30, the material of the second yarn 32 is different from the second yarns 12, 22 in the first and second embodiments but have high strength and high elongation at break, such as an elongation at break that is at least higher than the elongation of the main body structure under a predetermined tensile force, such as not less than 30%, 45%, or 50%. In the present embodiment, the material of the second yarn may be medium-density polyethylene (MDPE) or high-density polyethylene (HDPE) yarn or polyethylene (PE) yarn. For example, PE yarn has a strength of 2.6-4.2 g/D, and its elongation at break can reach 65%.

[0041] FIG. 6 schematically illustrates exemplary symmetrical arrangements of the failure indicator in the main body structure of the strap according to the invention, which can obtain different tensile strengths and the maximum impact peak forces of the strap. For example, one second yarn is inlaid straight in alternate rows of knitted loops of the main body structure (see the left side of FIG. 6); two second yarns are inlaid straight in each row of knitted loops of the main body structure (see the middle of FIG. 6); or two second yarns are inlaid straight in alternate rows of knitted loops of the main body structure (see the right side of FIG. 6). Similarly, the second yarn is knitted straight in plain stitch into a corresponding row of knitted loops in the main body structure, as shown in FIG. 6. In addition, each single second yarn can be used to form a plurality of straight yarn parts inlaid in the main body structure through a serpentine arrangement or a shape of homocentric squares. For example, instead of a single second yarn in FIG. 3, two second yarns are symmetrically arranged on both sides of the longitudinal central axis of the main body structure of the strap, and each second yarn forms three straight inlaid parts in a serpentine arrangement as shown in FIG. 3. Alternatively, multiple untwisted or twisted second yarns are integrated into the main body structure in a manner of weft insertion, and fixed to the main body structure in this state. As will be understood by a person skilled in the art, the number of the second yarn inlaid or woven in the main body structure and its arrangement may be selected as required.

[0042] In a further preferred embodiment of the invention, the second yarn 12, 22, 32 may be provided with a scale or has different colors in different sections. For

example, when such a strap is used in a suspension system of a safety helmet, it is possible to evaluate the force condition, such as the strength of the force, based on changes in the scale or changes in the length of the different sections after the tensile force is released. It is to be understood that the more and/or larger the protruded loops, the greater the exerted tensile force, whereby the protruded loops are able to reflect the level of impact that has been experienced.

[0043] Preferably, the color of the second yarn is different from that of the first yarn in order to distinguish between the two. For example, the first yarn is black, white, etc., the second yarn is yellow, red, etc., and vice versa.

[0044] According to another embodiment of the present invention, a safety helmet is provided, comprising a helmet body and a suspension system attached to the inside of the helmet body. The suspension system comprises a plurality of straps connected with a cushion pad to form a structure covering the head, wherein at least one of the plurality of straps is formed by a strap with a failure indicator according to the invention, such as the above-mentioned first, second and third straps, so that the suspension system can not only act as a buffer when subjected to a tensile force, but also can indicate whether the suspension system has experienced impact. Preferably, the plurality of straps are all formed by straps with a failure indicator and are symmetrically arranged in the helmet body. Preferably, at least one pair of straps of the plurality of straps are different in length from other straps, and the at least one pair of straps have a second yarn arrangement different from other straps. Generally, the vertical distance between the cushion pad and the helmet body is 25~50 mm, so preferably, the elongated lengths of the straps can be designed to ensure that the cushioning pad of the suspension system does not contact the helmet body. For example, for the strap structure in FIG. 2A, since the amount of deformation of the second yarn is very small, the elongated length of the strap can be limited by designing the total length of the compensating portion 17 (i.e., the total length of the second yarn in this portion). In other words, the elongated length of the strap is controlled by designing the length of the second yarn.

[0045] Those skilled in the art will understand that it is also possible to construct other safety devices from the strap with a failure indicator to indicate whether the safety devices have undergone an impact. For example, the safety device may be a safety harness worn on a person that is attached to a high anchor point to protect the person from falling from height. The safety harness is made of a plurality of straps connected together, at least one of which is formed by a strap having a failure indicator. For another example, the safety device may be a safety rope formed by a strap with a failure indicator.

[0046] The invention also provides a method for manufacturing a strap with a failure indicator, which comprises:

a) providing a first yarn;
b) providing a second yarn;
c) knitting the first yarn to form a main body structure of the strap, and integrating the second yarn straight into the main body structure and extending the entire length of the main body structure, and
d) fixing the second yarn at least partially to the main body structure;

wherein the main body structure and the second yarn are selected such that the main body structure and the second yarn are elongated and do not break under a predetermined amount of a tensile force, and after the tensile force is released, the main body structure retracts, such that at least one second yarn can at least partially protrude from the plane of the main body structure to form a failure indicating loop.

[0047] The strap is knitted using a fully automatic double-needle bed flat knitting machine in the following steps, as shown in FIG. 7:
in the unreinforced structure, the first yarn is knitted to have alternate rows of single-sided loops and double-sided loops, and the second yarn is inlaid in each row or in alternate rows of double-sided loops. Only double-sided loops are used in the reinforced structure, and the second yarn is inlaid in each row or in alternate rows of double-sided loops.

[0048] Preferably, in step c, the first yarn is knitted in the manner of plain weave, double-sided weave, jacquard weave, etc., to form the main body structure, so that the elongated length of the main body structure under a predetermined amount of a tensile force is substantially caused by the deformation of the orientation of the knitted loops and the straightening of the arcs of the loops.

[0049] Preferably, the method further comprises: in step b, winding a thermal fuse on the second yarn, the twist of the thermal fuse being preferably 6~10 tums/cm, and in step d, heating the strap to melt the thermal fuse to fix the second yarn to the main body structure. The thermal fuse is a low melting point thermal fuse with a melting point of 80~130°C, such as nylon thermal fuse. Therefore, the step of heating the strap is carried out by applying a temperature of 80~130°C to the strap, and the temperature can be applied by steam ironing or heat setting. In addition, the second yarn can be fixed to the main body structure in other ways, for example, the second yarn is fixed to the main body structure by means of an adhesive.

[0050] Preferably, the method further comprises: after step d, folding each end of the strap and fixing it in the middle with a suture to form a first bending portion and a compensating portion.

[0051] The invention realizes a simple, non-electronic, and cost-effective reliable solution which makes it possible to visually determine whether the strap and the safety device including the strap have experienced an impact simply by means of the second yarn. In addition, since the second yarn is inlaid in the main body structure

of the strap, it is possible to avoid breakage of the second yarn due to wear. Furthermore, the elongated length of the strap can be controlled by designing the compensating portion (i.e. the length of the second yarn in this portion) to achieve better protection.

[0052] The foregoing descriptions are only illustrative in nature and are not intended to limit in any way the disclosure, its application, or use. The broad teachings of the disclosure can be implemented in many forms. Further, while each of the embodiments is described above as having certain features, any one or more of those features described in any embodiment of the disclosure can be implemented in and/or in combination with the features of any of the other embodiments, even if the combination is not expressly described. In other words, the embodiments described are not mutually exclusive, and the arrangement of one or more embodiments with each other remains within the scope of the disclosure. Therefore, although the disclosure includes specific examples, the true scope of the disclosure should not be so limited. A person skilled in the art can make various modifications according to the teachings of the invention without deviating from the scope and spirit of the invention.

Claims

1. A strap with a failure indicator, comprising:

a main body structure formed by knitting; and
one or more second yarns integrated straight into the main body structure in a length direction of the main body structure along the entire length of the main body structure and at least partially fixed to the main body structure;
wherein the main body structure and the second yarn are selected such that the main body structure and the second yarn are elongated and do not break under a predetermined amount of a tensile force, and after the tensile force is released, the main body structure retracts, such that at least one second yarn at least partially protrudes from a plane of the main body structure to form a failure indicating loop.

2. The strap according to claim 1, wherein under the predetermined amount of the tensile force, an elongated length of the main body structure is greater than an elongated length of the second yarn, such that the second yarn detaches from the fixation to the main body structure and can slide in the main body structure; when the tensile force is released, the main body structure retracts, and the second yarn does not retract due to occurred plastic deformation, such that the length of the main body structure is smaller than the length of at least one second yarn that has slid, thereby the at least one second yarn at least partially protruding from the plane of the main body structure.

3. The strap according to claim 1, wherein under the predetermined amount of the tensile force, the second yarn deforms synchronously with the main body structure, and after the tensile force is released, the length of the main body structure after retraction is smaller than the length of at least one second yarn that has deformed plastically, such that the at least one second yarn at least partially protrudes from the plane of the main body structure.

4. The strap according to any of claims 1 to 3, wherein material of a first yarn forming the main body structure may be any of the following: polyester fiber, polyester low-elastic yarn, polyester high-elastic yarn, spandex core-spun material, polyester, polyamide, natural fiber, viscose fiber, acrylic fiber and acetate fiber, and the first yarn is of a different color from the second yarn.

5. The strap according to claim 1 or 2, wherein the second yarn has a tensile strength of at least 2.0 N/Tex, and the elongation at break in the range of 2~5%; the main body structure has the maximum tensile force of not less than 800 N, and the elongation in the range of 15%~35%.

6. The strap according to claim 1 or 2, wherein the strap has a compensating portion, which can compensate for the difference in elongated lengths between the main body structure and the second yarn under the predetermined amount of the tensile force.

7. The strap according to claim 6, wherein the compensating portion is formed by forming a bending portion at an end of the main body structure.

8. The strap according to any of claims 1 to 3, wherein the one or more second yarns are formed by a single yarn which is in a serpentine arrangement and turns at the ends of the main body structure.

9. The strap according to any of claims 1 to 3, wherein the fixation of the second yarn to the main body structure is realized by winding a thermal fuse at least partially around the second yarn with a twist of 6~10 turns/cm or by using an adhesive.

10. A safety device comprising a component formed by the strap with a failure indicator according to any of claims 1 to 9, to facilitate determining whether the safety device has been damaged.

11. A safety helmet, comprising a helmet body and a suspension system attached to the inside of the helmet body, the suspension system comprising a

plurality of straps connected with a cushion pad to form a structure covering a head, wherein at least one of the plurality of straps is formed by the strap according to any of claims 1 to 9, such that the suspension system can not only act as a buffer when subjected to a tensile force, but also can indicate whether the suspension system has experienced impact.

12. A method for manufacturing a strap with a failure indicator, comprising:

a) providing a first yarn;
b) providing a second yarn;
c) knitting the first yarn to form a main body structure, and integrating the second yarn straight into the main body structure and extending the entire length of the main body structure, and
d) at least partially fixing the second yarn to the main body structure;

wherein the main body structure and the second yarn are selected such that the main body structure and the second yarn are elongated and do not break under a predetermined amount of a tensile force, and after the tensile force is released, the main body structure retracts, such that at least one second yarn can at least partially protrude from a plane of the main body structure to form a failure indicating loop.

13. The method according to claim 12, wherein in step c, knitting the first yarn in a manner of plain weave, double-sided weave or jacquard weave to form the main body structure.

14. The method according to claim 12, further comprising: in step b, winding a thermal fuse around the second yarn along at least part of the length of the second yarn and, in step d, melting the thermal fuse by heating the strap to at least partially fix the second yarn to the main body structure.

15. The method according to claim 14, wherein a melting point of the thermal fuse is 80~130°C and its twist is 6~10 turns/cm.

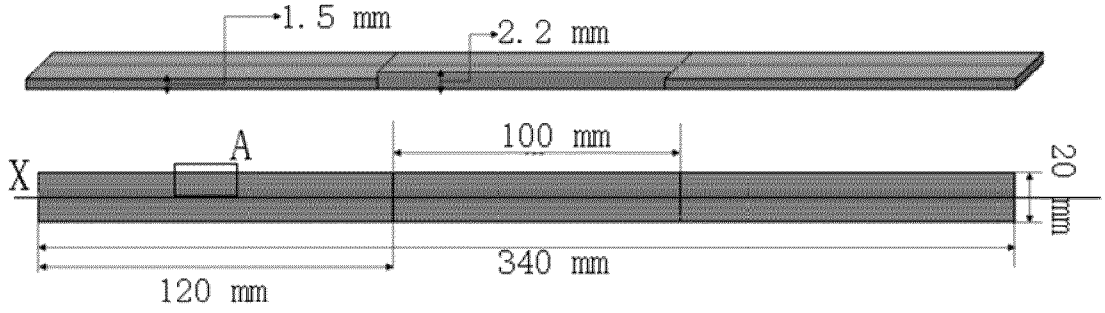


Fig. 1A

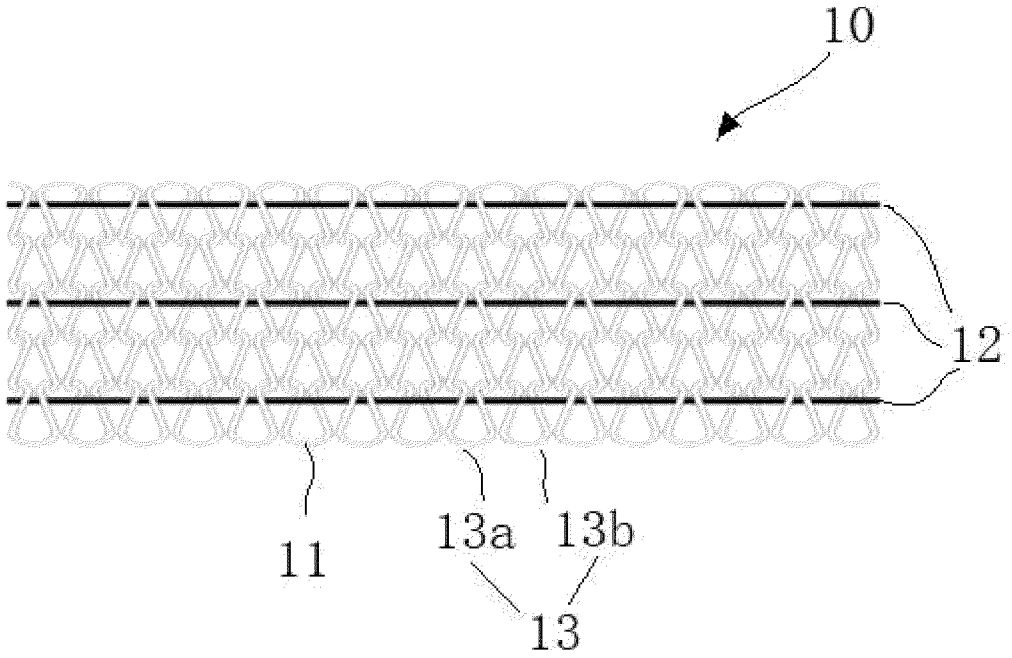


Fig. 1B

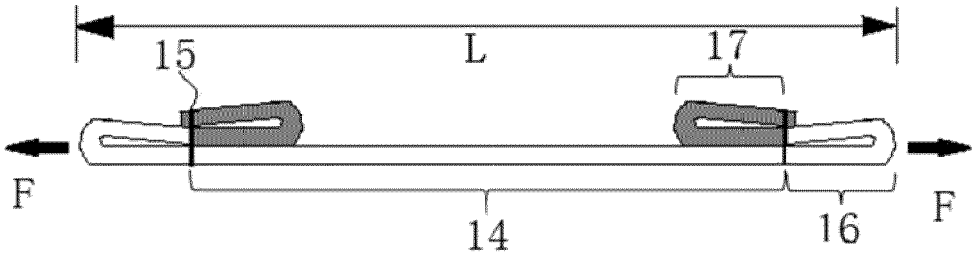


Fig. 2A

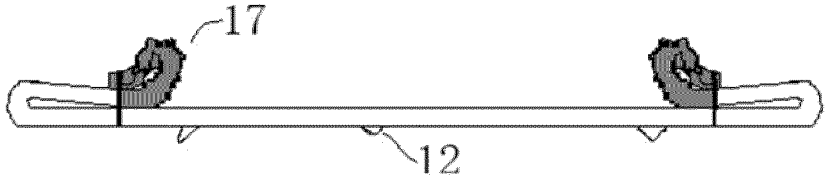


Fig. 2B

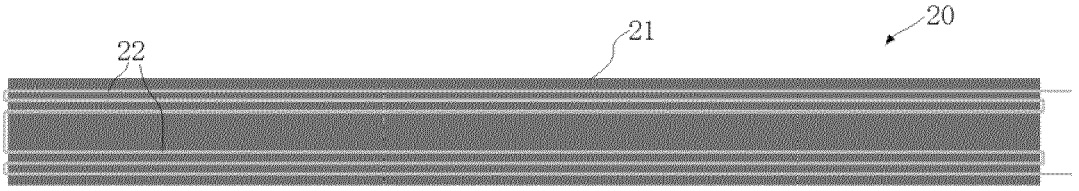


Fig. 3

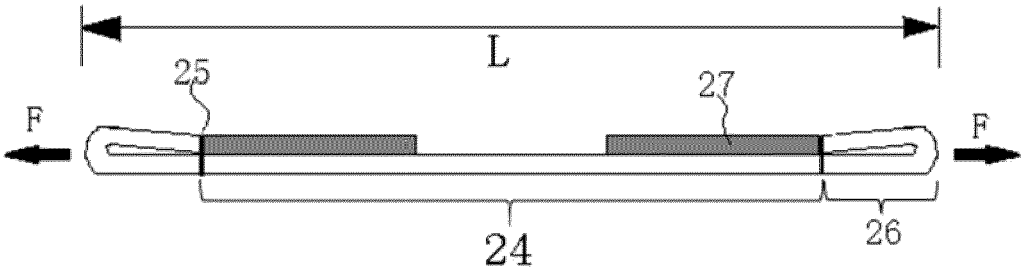


Fig. 4A

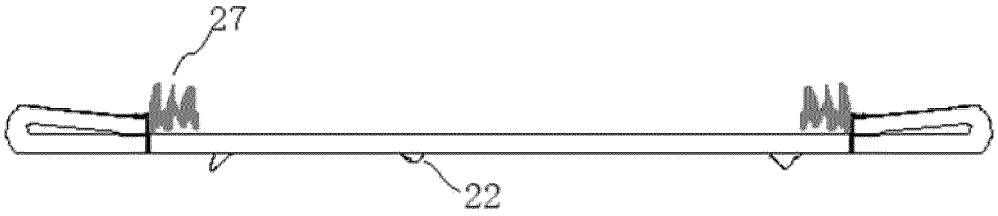


Fig. 4B

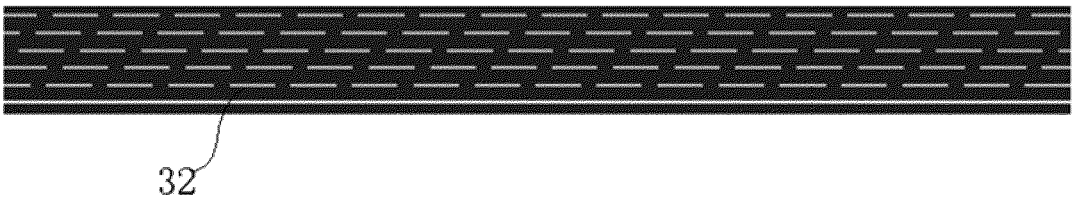


Fig. 5A

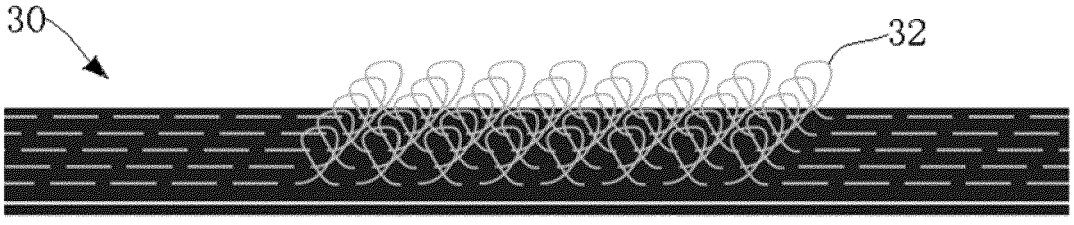


Fig. 5B

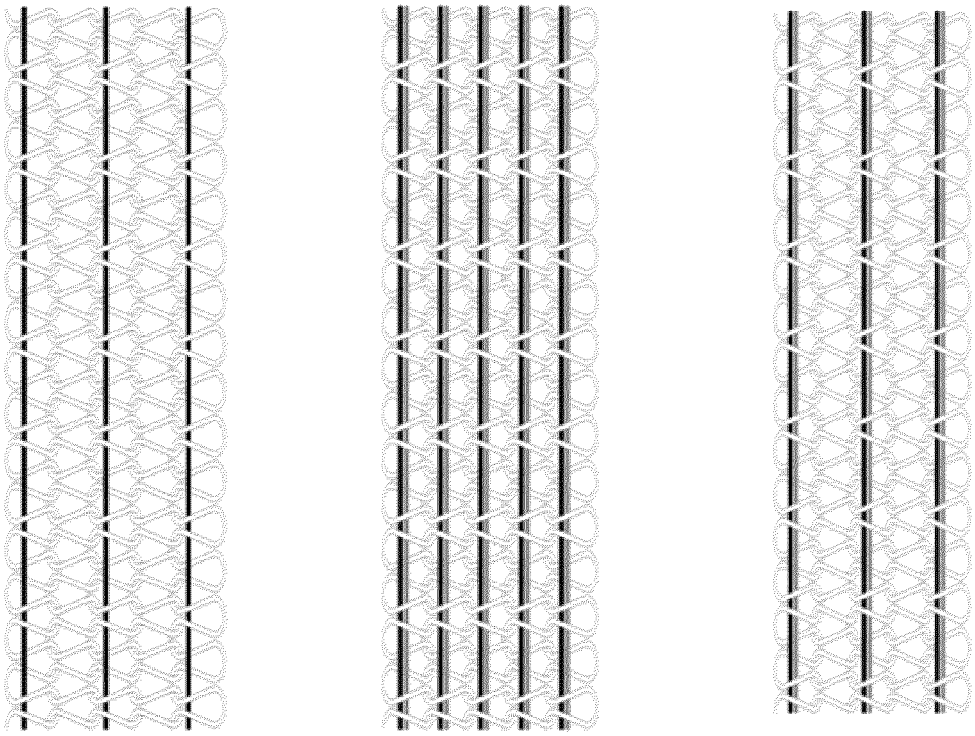
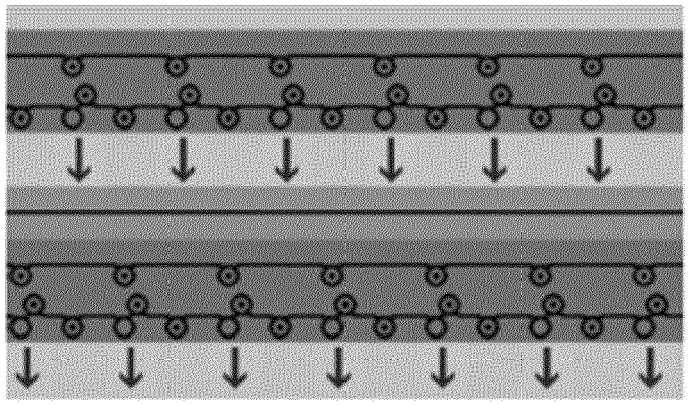


Fig. 6


One-sided alternate loops
Double-sided loops
Reverse
Second yarn
One-sided alternate loops
Double-sided loops
Reverse

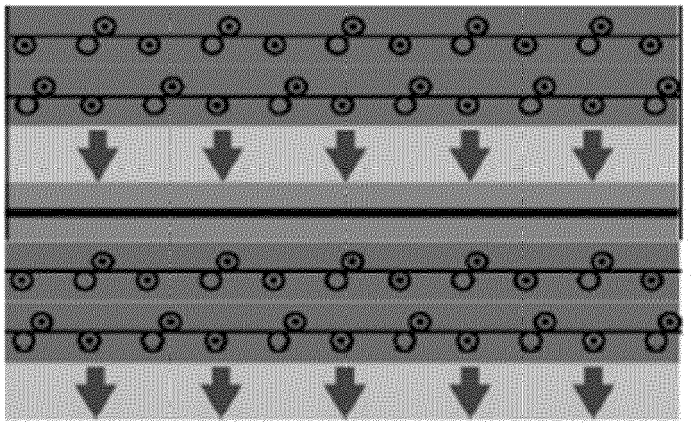

Double-sided loops
Double-sided loops
Reverse
Second yarn
Double-sided loops
Double-sided loops
Reverse

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 24 19 4875

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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A	US 2008/290643 A1 (HANSEN HOLGER [DE]) 27 November 2008 (2008-11-27) * abstract; figures 1,2 * * paragraph [0004] - paragraph [0005] * * paragraphs [0014], [0018] *	1-15	
A	EP 4 201 243 A1 (3M INNOVATIVE PROPERTIES COMPANY [US]) 28 June 2023 (2023-06-28) * abstract; figures 1-18B * * paragraph [0038] - paragraph [0042] * * paragraph [0047] * * paragraph [0059] - paragraph [0061] *	1-15	
A	US 2002/000004 A1 (WISE LAYTON A [US] ET AL) 3 January 2002 (2002-01-03) * abstract; figures 1-5B * * paragraph [0042] *	1-15	TECHNICAL FIELDS SEARCHED (IPC) A42B A41D A62B B60R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	31 January 2025	Thielgen, Robert

CATEGORY OF CITED DOCUMENTS

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