



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
30.08.2023 Bulletin 2023/35

(51) International Patent Classification (IPC):
D04B 1/24 (2006.01)

(21) Application number: **22382157.0**

(52) Cooperative Patent Classification (CPC):
D04B 1/246; D04B 1/243; D10B 2401/06

(22) Date of filing: **23.02.2022**

(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

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(54) **PROTECTIVE GARMENTS MADE FROM AUXETIC SEAMLESS KNITTED FABRIC COMBINED WITH NON-NEWTONIAN FLUIDS**

(57) The present invention relates a protective garments made from auxetic seamless knitted fabric combined with non-newtonian fluids. The protective garment (1) of the present invention comprising at least one of the following layers: a first layer (2) made of an auxetic seamless knitted fabric having a structure with a pattern such that the pattern comprises parallel columns of fibers with a gap between each two adjacent columns, and a second layer (3) made of an auxetic seamless knitted fabric hav-

ing the same structure and fibres of the first layer (2), wherein the fibers of the second layer (3) are impregnated with a non-Newtonian fluid. The protection offered by the garments of the present invention is due to the combination of the type of structure and materials of fibers plus the impregnation with non-Newtonian fluids. Thanks to the combination of both technologies, the protective garment can be used in different fields such as defence applications, sports or medicine.

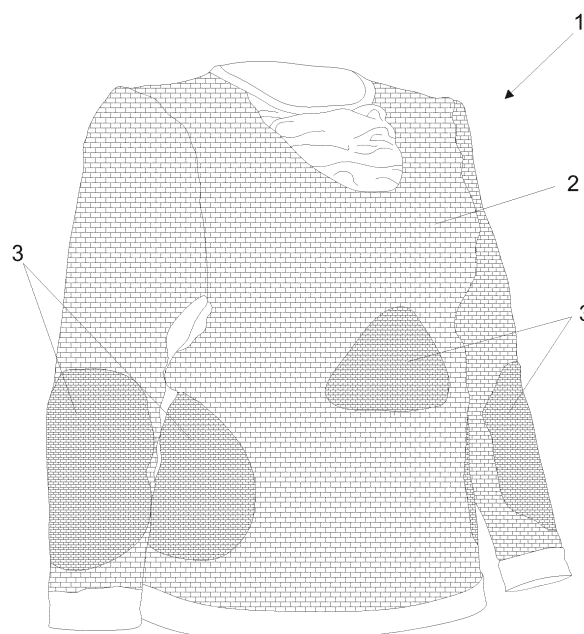


Fig. 3

Description

FIELD OF THE INVENTION

[0001] The present invention relates to protective garments made from the auxetic fabric combined with non-Newtonian fluids.

BACKGROUND ART

[0002] Auxetic materials are different from most conventional materials in that they exhibit a negative Poisson's ratio (NPR). They expand laterally when stretched and contract laterally when compressed. This counterintuitive behaviour gives auxetic materials various beneficial effects, such as enhanced shear stiffness, increased plane strain fracture toughness, increased indentation resistance, and improved energy absorption properties [1,2].

[0003] At present, auxetic materials can be produced in different materials including polymers, metals, ceramics, and composites [3]. For example, auxetic materials are used in composite materials to promote fibers reinforcement in textiles for crash helmets and sports clothing, as sponges, as ropes, in filtration and as shock absorbing materials [4]. They have a lot of potential applications, from biomedical to automotive and defence industries. Also, these materials could potentially be used for completely new structures with special functions [5].

[0004] Auxetic materials stand out for their unique characteristics that allow their use in numerous applications. The main inherent characteristic of these materials is the stretching behaviour of the cross-section when there is tension in the longitudinal section. This particularity endows the material with unique characteristics, both from a functional and visual point of view.

[0005] Compared to common materials, due to this behaviour and intrinsic characteristics, auxetic materials also stand out for their high resistance to fracture and shear. If the material presents a crack, in the expansion process the crack tends to be closed due to transversal elongation. Furthermore, the fact that this type of materials assumes a synclastic curve when submitted to an out-of-plane stress allows the material not to be forced to assume an unstable conformation, thus decreasing the probability of fracture [6].

[0006] The properties of auxetic materials give them unique characteristics in behaviour and response to impacts, as well as energy absorption and physical change in response to external forces [6].

[0007] On the other hand, in the area of materials that, thanks to their characteristics, can be used for protection products or equipment, it also stands out the non-Newtonian Fluids. The main characteristic of non-Newtonian Fluids is that they do not follow Newton's laws, i.e., constant viscosity independent of stress. The viscosity of these materials is dependent on the shear rate. Within this class of materials, shear thickening fluids (STF)

stand out, which, when subjected to forces, suffer an increase in apparent viscosity as the particles tend to agglomerate, forming layers as a consequence of the disordered state they reach. Thus, the greater the application of force, the greater the tendency of the particles to aggregate, and the increase in viscosity intensifies.

[0008] The behaviour referred to occurs quite frequently in colloidal suspensions, with agglomeration of the solid particles being observed [7]. Therefore, when this type of material is subjected to high-speed shear rates, the increase in viscosity allows the material to behave as a solid. Once the application of this stress is terminated, the material/substance returns to its original state [7, 8]. These characteristics make these materials ideal for the area of protection, being able to provide impact protection at either high or low velocity.

[0009] The combination of these two technologies is attractive for developing new products or equipment with high impact resistance, such as personal protective equipment or garments, but also garments for high-impact sports. Furthermore, auxetic materials have these properties have potential for use in a number of defence applications.

[0010] US2020221816A1 describes a footwear cover that includes a sole portion, that at least partially comprises an auxetic structure, that includes an inner layer and an outer layer that cooperate to define at least a first interior space there between, at least a first bladder member disposed in the first interior space, and an upper connected to the sole portion. The first bladder member defines a bladder interior that includes a non-Newtonian fluid disposed therein.

[0011] US2018027893A1 describes a protective garment system for protecting an individual and methods of using the same. The invention describes an active layer can include any suitable energy-responsive material that changes at least one physical property thereof responsive to receiving the stimulus energy. The energy-responsive material can include at least one of an electrorheological fluid, a magnetorheological fluid, an electroactive polymer, a non-Newtonian fluid, or an auxetic material. However, the protection system described by this invention requires many layers of complex materials, which implies greater manufacturing complexity and higher cost.

[0012] Therefore, there is a need for protective garments that offer high impact/shock resistance while providing comfort for the user and durability.

SUMMARY OF INVENTION

[0013] In view of the problems of the prior art, the main object of the present invention is to provide a protective garment made from an auxetic fabric. The protection offered by the garments of the present invention is due to the combination of the type of structure and materials of fibers plus the impregnation with non-Newtonian fluids.

[0014] Thanks to the combination of both technologies,

the protective garment can be used in different applications, offering a range of products to the user with the following advantages: greater modular protection (adaptable to the needs of the activity/user), breathable, comfortable, and ergonomic.

[0015] In a first aspect, the present invention refers to a protective garment comprising at least one of the following layers:

- a first layer of an auxetic seamless knitted fabric having a structure with a pattern such that the pattern comprises parallel columns of fibers with a gap between each two adjacent columns, and
- a second layer made of an auxetic seamless knitted fabric having the same structure and fibres of the first layer, wherein the fibers of the second layer are impregnated with a non-Newtonian fluid.

[0016] Preferably, the fibers of the fabric have between 80-90% of polyamide and between 10-20% of elastane.

[0017] Preferably, the non-Newtonian fluid is a Shear thickening fluid (STF). STF is a kind of non-Newtonian fluid, where the shear stress is not linearly related with the shear rate. The viscosity of fluid increases as shear rate or applied stress increases on the medium.

[0018] In the present invention, "protective garment" includes all type of garments that assist with protecting a user from various types of injuries, damages or shocks, such as injury due to falling, being struck by an object or due to contact with other people. These protective garments can be used in different fields such as defence applications, sports or medicine.

[0019] Garments in accordance with the present invention may comprise tights, sleeves for arms, sleeves for legs, socks, shirts, or any other type of garment that may be worn on the portion of the user anatomy where protection is desired.

BRIEF DESCRIPTION OF DRAWINGS

[0020] The following figures are described below. These illustrate the exemplary embodiments and are not limiting their scope.

Figure 1 shows the structure of the fabric of the first and second layer.

Figure 2 shows a back view of a shirt made with the first and the second layer of the invention.

Figure 3 shows a frontal view of a shirt made with the first and the second layer of the invention.

Figure 4 shows a frontal view of a tights made with the first and the second layer of the invention.

Figure 5 shows a back view of a tights made with the first and the second layer of the invention.

DESCRIPTION OF EMBODIMENTS

[0021] The protective garment (1) of the present inven-

tion comprising at least one of the following layers:

- a first layer (2) of an auxetic seamless knitted fabric having a structure with a pattern such that the pattern comprises parallel columns of fibers with a gap between each two adjacent columns, and
- a second layer (3) made of an auxetic seamless knitted fabric having the same structure and fibres of the first layer, wherein the fibers of the second layer are impregnated with a non-Newtonian fluid.

[0022] Figure 1 shows the pattern of the first (2) and the second (3) layer of the protective garment (1).

[0023] Figures 2-5 illustrates several protective garments (1).

[0024] In a first embodiment (figures 2 and 3), the protective (1) garment is a shirt that comprises the first layer (2) in the entire garment and the second layer (3) located on the lower part of the sleeves, the central part of the chest and the sides of the garment.

[0025] In a second embodiment (figures 4 and 5), the protective (1) garment is a tight that comprises the first layer (2) in the entire garment and the second layer (3) located in the central part of shins and thigh area.

[0026] In the present invention it has been possible to produce an auxetic structure which, combined with the fibres used, allows the construction of seamless garments with an active behaviour. In addition, impregnation with non-Newtonian fluids offers additional advantages. This makes it possible to customize protection levels and zones according to the final application of the product.

[0027] Being able to work with different levels of protection and having modularity allows for the ideal level of protection for the areas of the body most susceptible to injury/impact, such as the legs, head, limbs and torso.

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Claims

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1. A protective garment (1) comprising at least one of the following layers:

- a first layer (2) made of an auxetic seamless knitted fabric having a structure with a pattern such that the pattern comprises parallel columns of fibers with a gap between each two adjacent columns, and 20

- a second layer (3) made of an auxetic seamless knitted fabric having the same structure and fibres of the first layer (2), wherein the fibers of the second layer (3) are impregnated with a non-Newtonian fluid. 25

2. The protective garment (1) according to claim 1, wherein the fibers of the fabric have between 80-90% of polyamide and between 10-20% of elastane. 30

3. The protective garment (1) according to claim 1, wherein the non-Newtonian fluid is a Shear thickening fluid (STF). 35

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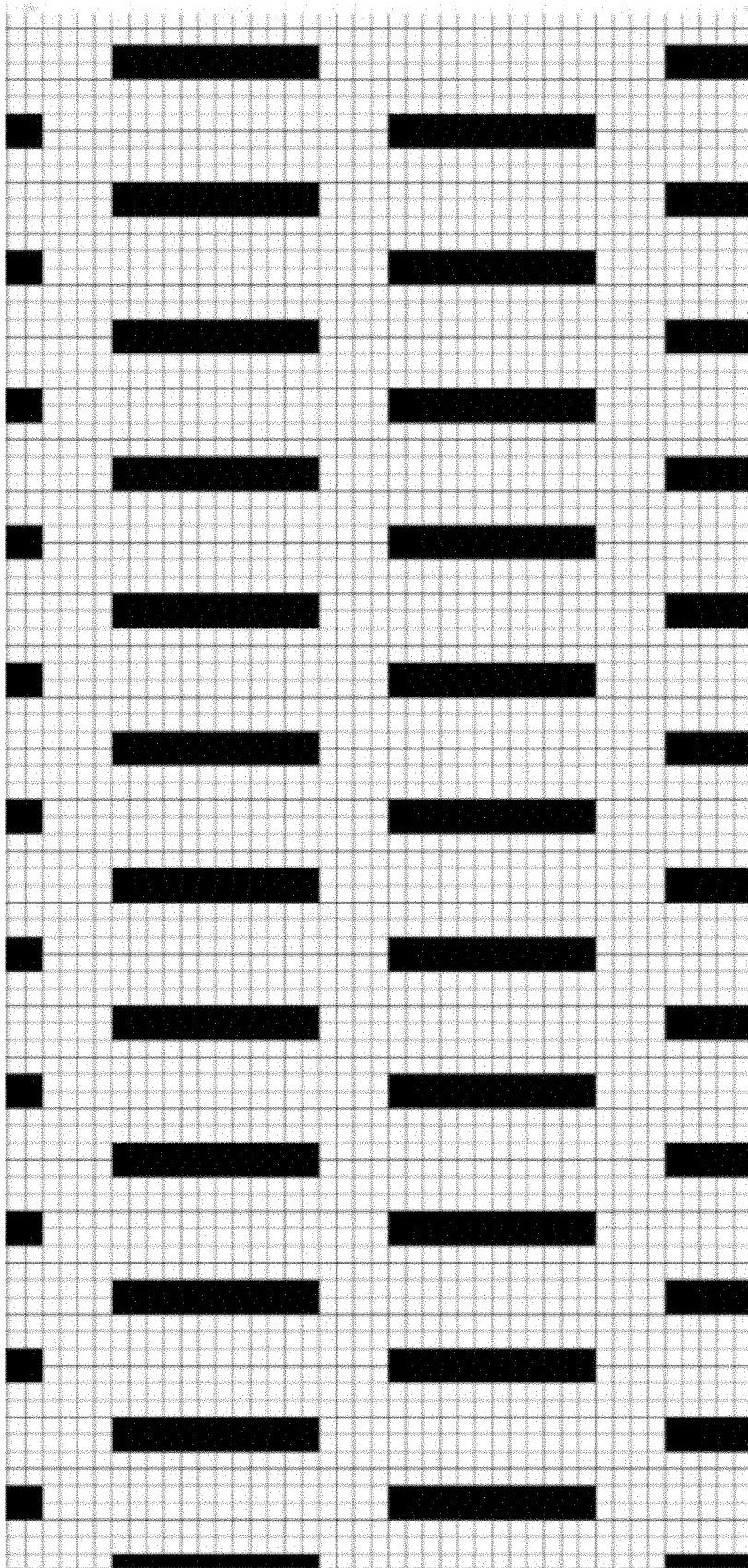


Fig. 1

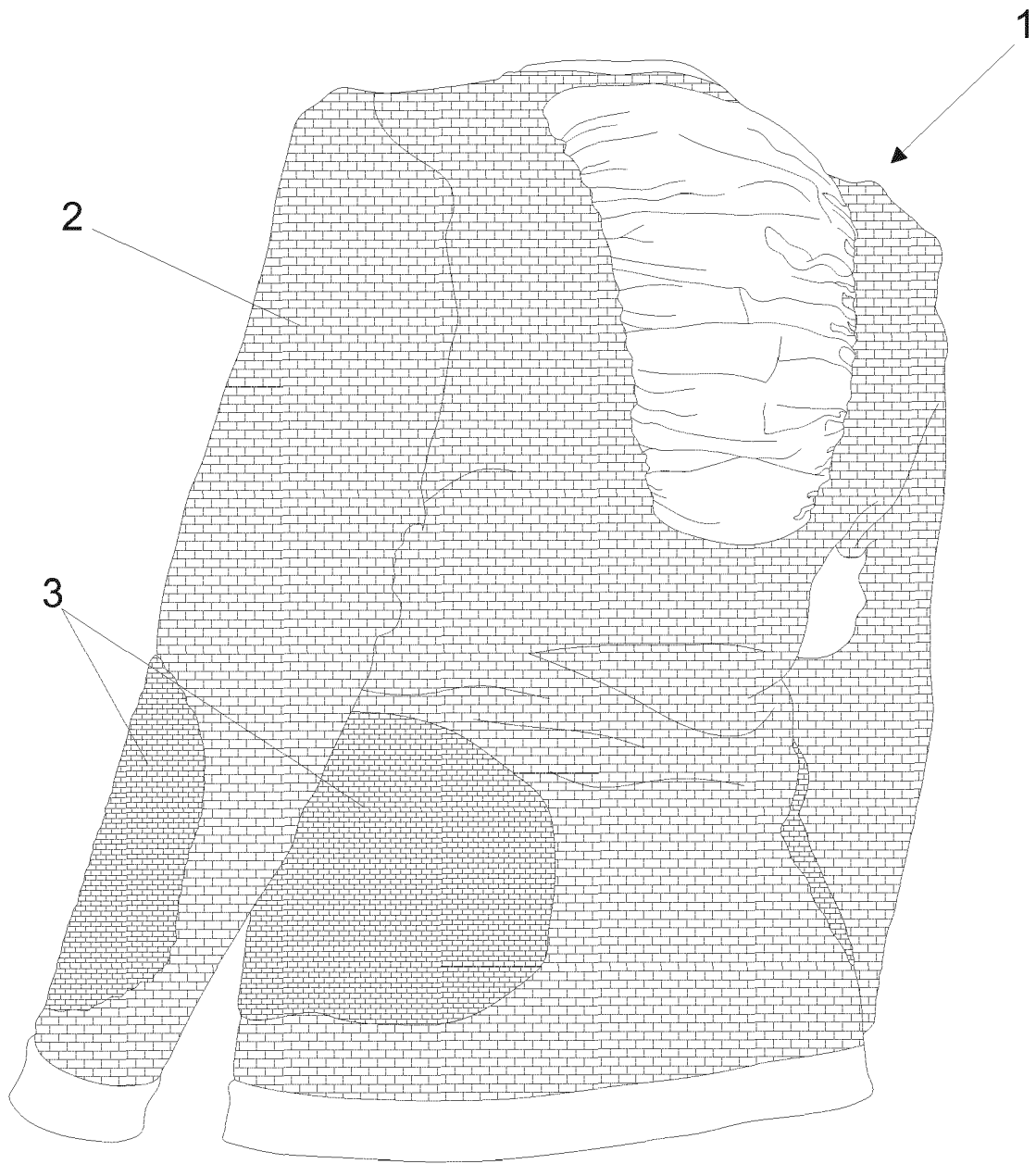


Fig. 2

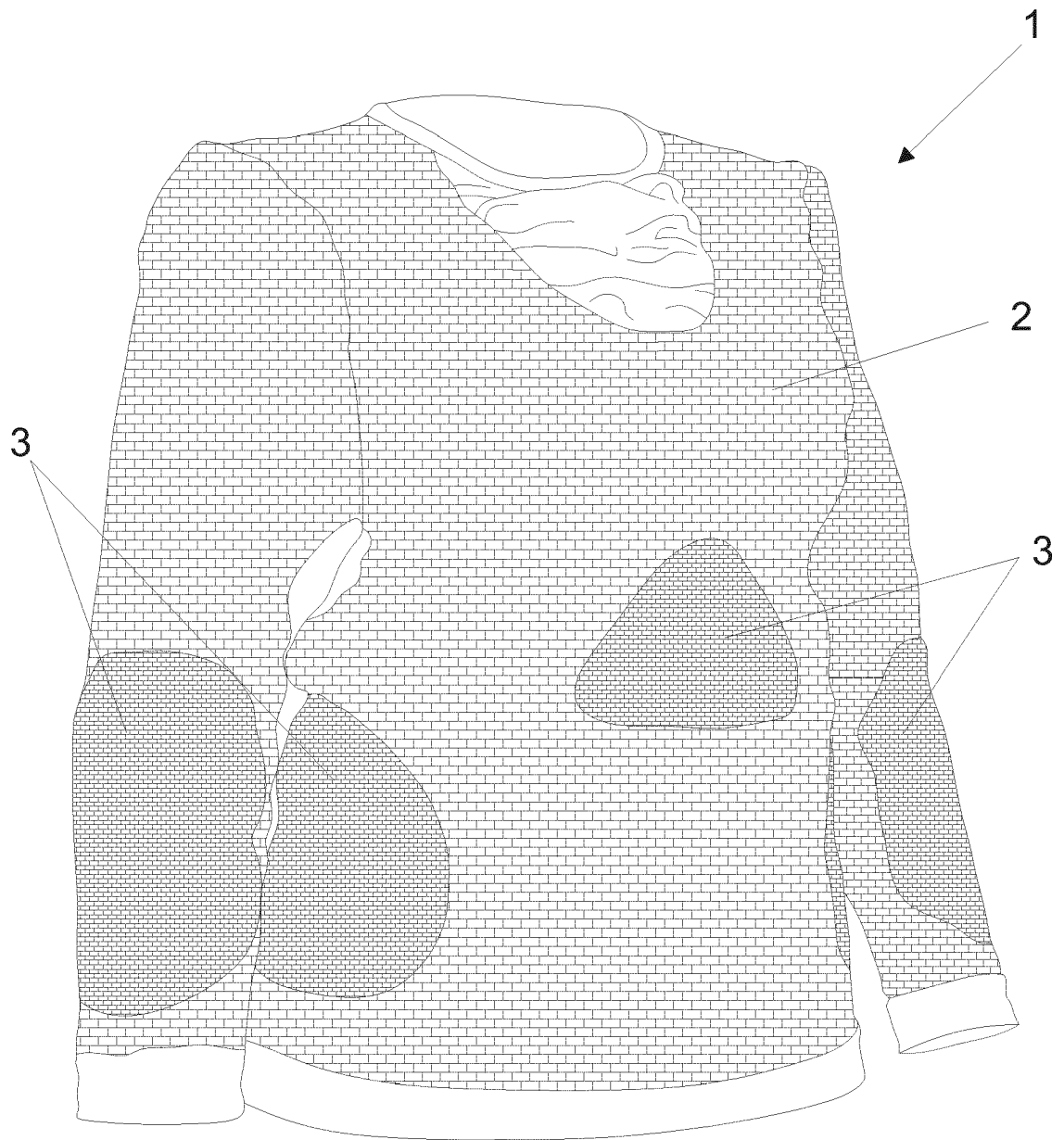


Fig. 3

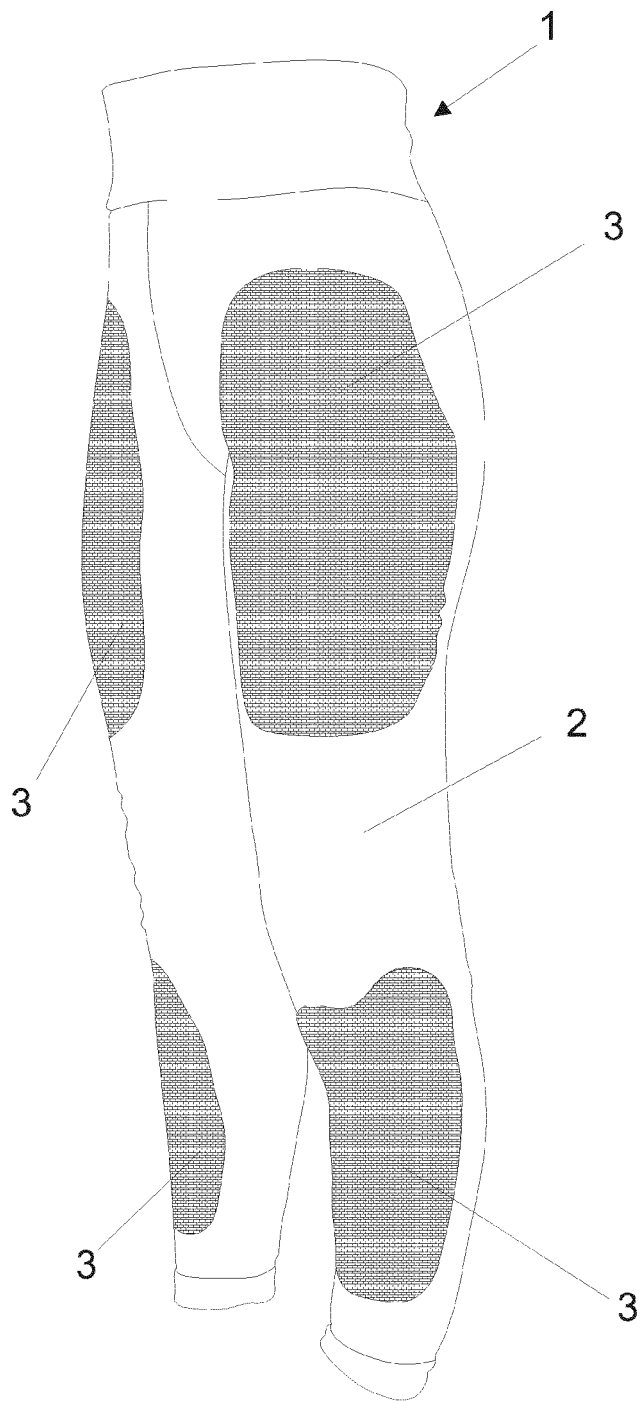


Fig. 4

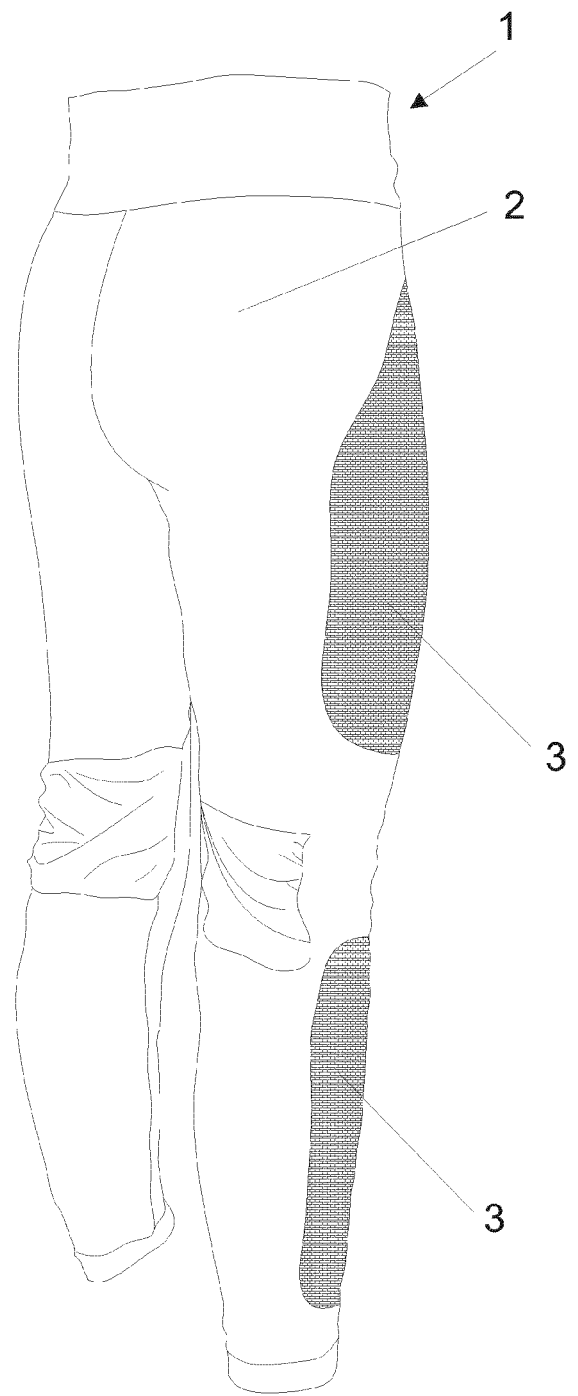


Fig. 5



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Application Number

EP 22 38 2157

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