Textile substrate with structurally integrated, destructible threads to facilitate material separation

Field of the invention

The present invention relates to textile substrates, in particular those produced as knitted fabrics by means of a weft and/or warp knitting technique. The invention further comprises the use of these textile substrates as well as methods for processing them. The areas of application for these textile substrates are diverse and include, amongst others, clothing, interior furnishings and technical textiles.

Background of the invention

The present invention therefore operates in the field of textile technology and focuses on the development of textile substrates produced by means of a weft and/or warp knitting technique. The current need for sustainable practices in the textile industry is particularly acute in view of the significant environmental impact caused by textile waste and the strict regulatory requirements aimed at promoting environmentally friendly approaches.

Conventional textile products, which often consist of blends of different fibre types, including natural, artificial and synthetic fibres, pose major challenges for recycling, particularly with regard to the efficient separation of materials after use. These complex fibre blends lead to significant challenges in the recycling process, as the efficient separation of materials is technically difficult to achieve. Existing technologies, such as the ‘Dualcycle’ process described in European Patent EP 2 532 775 B1 and the methods set out in Japanese patent documents, such as JP H08 81811 A, offer the recyclability of woven textiles. In particular, the ‘Dualcycle’ process describes the manufacture of textile substrates in which warp and weft threads, consisting of different, potentially recyclable materials, are crossed at right angles using weaving techniques and arranged in a single layer. This technology promises easier separation of the woven materials at the end of the product’s life. Whilst the patented claims in this process describe the separation of single-layer groups of materials with different material properties in woven fabrics, they fail to apply to knitted fabrics, as they relate to weaving processes and do not account for the logic of forming and breaking bonds within knitted fabrics, nor for standard knitting processes such as plating (an additional thread

is fed in parallel to a key area-forming thread within the same stitch system, whereby this additional thread follows exactly the same path as the key area-forming thread but is of a different material composition), which is an essential prerequisite for effective recycling and minimal environmental impact.

Against this background, there is a need for an innovative methodology for developing textile substrates in the form of knitted fabrics, which takes into account the specific requirements of the structure of the fabric for effective recycling at the end of the service life of the textile substrate. Knitted fabrics, which offer considerable sustainability potential due to their structural properties and their high share of global textile production, are the focus of this invention.

The invention presented here therefore aims to lay the foundations for improved recycling of textile knitted fabrics formed from mixed materials through detachable joining technology – referred to here as the 'textile screw' – in order to address the challenges posed by the current waste problem and the need for resource efficiency in the textile industry. With 'Design for Disassembly', the invention presented here paves the way towards recycling economy for textiles.

Summary of the invention

The aforementioned objective is achieved by providing a textile substrate in accordance with the features of patent claim 1, the use of such a textile substrate in accordance with the features of patent claim 9, and a method for processing such a textile substrate in accordance with the features of patent claim 10. Further developments of the textile substrate according to the invention are defined in patent claims 2 to 8.

Specifically, a textile substrate according to the invention, formed as a knitted fabric produced by means of a weft knitting and/or warp knitting technique, comprises: first threads, each of which is formed from one or more materials of a first material group; second threads, each of which is formed from one or more materials of a second material group; and third threads, which are formed from a destructible material of a third material group, which can be destroyed by means of a chemical and/or physical process. It is assumed that the first threads and the second threads are variously utilisable, or that each material of the first material group are variously utilisable compared to each material of the second material group.

Furthermore, the textile substrate is configured such that, in at least one region of the textile substrate, a connection between first threads and second threads is established by arranging at least one of the third threads in the at least one region of the textile substrate in such a way that the at least one of the third threads in the at least one region spatially connects first threads and second threads in that the at least one third thread in the at least one region crosses one or more first threads and one or more second threads alternately, so that the connection between the first threads and the second threads in the at least one region is realised exclusively by the at least one of the third threads.

In this context, the aforementioned wording ‘the at least one of the third threads in the at least one region spatially connects first threads and second threads in that the at least one third thread in the at least one region crosses one or more first threads and one or more second threads *alternately*’ is intended to define that the at least one third thread, in one portion of the at least one region of the textile substrate, *crosses* one or more first threads *on one of the two opposing outer sides of the textile substrate,* and the at least one third thread, in another portion of the at least one region of the textile substrate, *crosses* one or more second threads *on the other of the two opposing outer sides of the textile substrate*.

The aforementioned specification that ‘the connection between the first threads and the second threads in the at least one region is realised exclusively by the at least one of the third threads’ means, in this context, that there is no direct interlacing between any of the first threads and any of the second threads in the at least one region.

This technique allows for a flexible and versatile design of the textile structure, which facilitates the efficient integration of different fibre types into a single product. This is particularly advantageous as it enables specific functional and aesthetic properties to be achieved through the combination of different materials.

The textile substrate consists of a first material group, for example formed from skin-friendly cotton, which ensures comfort and breathability. The second material group may, for example, be formed from a highly elastic polyamide, which offers additional durability and supports the thermoregulatory properties of the textile substrate. This exemplary combination of materials optimises comfort and functionality. Through the special connection of the third material group, comprising a destructible material, with the first and second material groups, the extent of interaction between a material of the first material group and a material of the second material group can also be controlled. The claimed method is thus able to meet the

challenges of enhanced comfort, wear resistance, etc., in a unique way.

A key feature of the textile substrate is the integration of the third material group, which consists of one or more destructible materials. The third threads, formed from one or more materials of this third material group, can be destroyed by chemical or physical processes, which enables the separation of the various material components, i.e. the separation of the first threads from the second threads, once the textile substrate has reached the end of its service life. This targeted destructability is crucial for the recycling and sustainable reuse of the materials, as it enables the textile substrate to be broken down into its individual components, i.e. the respective materials of the first material group and the respective materials of the second material group, at the end of its service life, allowing them to be recycled separately by material type.

The specific arrangement of the third, destructible material group connects the other two material groups spatially, in that, as viewed from the perspective of the third, destructible material group, they are each situated on opposite sides of the textile substrate; whilst they may well lie opposite one another in the two-dimensional configuration of the outer sides of the textile substrate, this is not strictly necessary. This configuration supports the structural integrity of the textile substrate during its use and facilitates the separation of the materials following the destruction of the third material group.

An expedient embodiment of the invention provides that the first threads and/or the second threads are arranged in a defined pattern designed to enable specific functional and/or aesthetic properties of the textile substrate.

This embodiment, in which the materials of the material groups are arranged in a defined pattern, offers significant advantages. It enables adaptation to specific functional and aesthetic requirements, which is particularly valuable for sportswear and technical applications. Furthermore, the ordered thread structure facilitates recycling, which increases the efficiency of the process and enables compliance with environmental standards such as the EU’s Green Deal, whilst supporting the eco-design guidelines contained therein by laying the foundation for what is known as ‘design for disassembly’.

A further particularly expedient embodiment of the present invention may be that the destructible material of the third material group consists of a specially formulated polymer that can only be destroyed by specific factors.

This embodiment focuses on destructible materials of natural or synthetic origin within the third material group, which react to specific factors beyond their intended use: for example, significant temperature changes, exposure to an aqueous medium, pressure, intense radiation, certain chemicals, and/or combinations thereof. The main advantage of this embodiment is the targeted and controlled destructability, occurring only under specific circumstances, which simplifies the separation and recycling of materials in the first material group and those in the second material group, without compromising the product's functionality or damaging the recyclable materials themselves, that is, the materials in the first and/or second material groups. This environmentally conscious solution reduces textile waste and supports sustainable practices in the textile industry, which is in line with regulatory requirements such as the EU's Green Deal; this is also achieved because the specific bonding of the material groups to one another results in an extended service life of the textile substrate, whilst simultaneously increasing efficiency in material recycling.

The aforementioned embodiment can also be further optimised by using specially formulated polymers as a material in the third material group, which are able to be actively broken down by temperature fluctuations within a predefined range, by long-term exposure to radiation and/or by sustained high humidity conditions at certain temperatures, or even by chemical influences such as strongly alkaline or strongly acidic conditions, either alone or in combination with such exposures, e.g. in future also through industrial composting or specific treatment in a suitable facility such as an autoclave.

This further development specifies the destructability of the polymer under defined influences, taking into account the most optimal and cost-effective process for targeted destructability, enabling highly efficient separation of the material components at the end of the textile substrate's life cycle, supported by environmentally friendly disposal and optimised recycling. Precise control of the destruction process maximises the service life of the textile substrate and facilitates the conservation of resources by making the recycling process more efficient and reducing waste.

In yet another preferred embodiment of the textile substrate according to the invention, the textile substrate additionally comprises layers or coatings which are designed to be compatible with the materials of the first, second and third material groups and do not impair their separability or recyclability.

Compatibility with the main materials of the substrate does not merely relate to their

usefulness; rather, it ensures that they do not impair separability and recyclability. These layers also provide effective protection against water, UV radiation and microbial damage. This not only increases the service life and functionality of the textile substrate, but also supports sustainable recycling processes and thus contributes to reducing environmental impact.

In the case of a textile substrate according to the invention, it may also preferably be provided that the third threads are integrated into the textile substrate in such a way that they are arranged transversely to the second threads and the third threads, and thus, through their spatial arrangement, support the structural integrity of the textile substrate during use of the textile substrate, wherein the arrangement of the third threads enables the first threads to be easily separated from the second threads, or the materials of the first material group to be easily separated from the materials of the second material group, following the destruction of the destructible material of the third material group, without any structural impairment to the first threads and the second threads during a recycling process.

This preferred embodiment emphasises the third threads of the third material group, formed from destructible material and arranged transversely to the first and second threads within the textile substrate, such that these third threads contribute significantly to the structural integrity of the textile substrate. This arrangement facilitates efficient separation of the materials during recycling, enabling the materials to be separated without structural damage. This facilitates the recycling process and improves sustainability through more effective reuse of the materials, which is consistent with environmentally friendly production practices and regulatory standards.

A further preferred embodiment of the textile substrate according to the invention is subjected to a post-treatment, such as calendering or, for example, a silicone coating, in order to improve physical properties, such as tear strength, colour fastness and/or shrinkage resistance, of the textile substrate without compromising its recyclability. The key advantage of this embodiment is that it improves the physical properties of the textile substrate without compromising its recyclability. This promotes the production of durable textiles that can nevertheless be recycled in an environmentally sound manner.

The textile substrate may be designed such that the destructible material of the third material group is configured in such a way that, following the destruction of the destructible material of the third material group by means of the chemical and/or physical process, the specially formulated polymer adheres to the first threads and/or the second threads as a polymer film,

thereby increasing the strength of the first threads and/or the second threads.

Furthermore, in a textile substrate according to the invention, it may preferably be arranged such that, following destruction, the third destructible material group adheres as a polymer film to the first threads (first material group) and the second threads (second material group), thereby reducing, in a dissolved state, the adhesion between the first threads of the first material group and the second threads of the second material group whilst wet, and/or, in the dried state of the textile substrate, which has already been separated into materials of the first material group and materials of the second material group, increasing the strength of the materials of the first material group and the second material group to be recycled by material type.

This preferred development of the invention facilitates the separation of the materials of the first and second material groups in the textile substrate without damaging their structural integrity, whilst at the same time strengthening the recycled material for subsequent processes, which may be mechanical. This development of the invention is of particular significance in the case of combinations of fibre and material groups with very different load-bearing properties; one might think, for example, of blends of cashmere and polyamide. Whilst cashmere is very fragile as a recyclable material during processing, and it is therefore highly beneficial to strengthen its structural integrity during the separation process using the polymer film of the third destroyed material group, a similar coating does not interfere with the recycling process for polyamide, which is entirely different.

The improved separability and/or reinforcement of structural integrity makes recycling more efficient and environmentally friendly by optimising the reuse of materials, thereby contributing to the reduction of textile waste. This technology therefore makes a significant contribution to promoting sustainable practices in the textile industry.

Finally, the aforementioned development of the invention can preferably be further improved such that the liquor produced by the separation process consists of biodegradable polymers. Such materials include, for example, polyvinyl alcohol from Kuraray or polylactides, e.g. from Natureworks LTD, and, where appropriate, specifically modified polyester types.

This improved variant offers an environmentally friendly solution by providing biodegradable polymers for the textile substrate, which can be discharged into sewage treatment plants in an aqueous solution, meaning they can be broken down there. These properties significantly improve the recyclability of the textiles by avoiding the generation of environmentally

problematic wastewater streams and by supporting more efficient and environmentally friendly processing – including that of waste by-products.

A textile substrate according to the invention is suitable for use as a textile substrate for all types of knitted fabrics, such as clothing, interior furnishings or technical applications, which enable the subsequent separation and recycling of different material components (materials of the first material group and materials of the second material group).

A method according to the invention for processing a textile substrate of the type mentioned above comprises the steps of:

a) applying a chemical and/or physical process to destroy the destructible material of the third threads,

b) mechanically separating the first threads from the second threads without causing structural damage to these threads, and

c) collecting the separated threads for recycling, wherein the destruction of the destructible material is carried out in such a way that a spatial separation of the first threads from the second threads is enabled by the specific spatial arrangement of the third threads.

In step c), the method advantageously enables particularly simple separation of the first threads from the second threads, since, in the at least one region of the textile substrate according to the invention, a spatial connection between the first threads and the second threads is realised exclusively by the at least one of the third threads and, accordingly, there is no direct interlacing in the at least one region between any of the first threads and any of the second threads. Once the destructible material of the third threads has been destroyed, the first threads are no longer bound to the second threads and can be easily separated from the second threads in the at least one region by means of mechanical separation.

Brief description of the drawings

Further features and advantages of the invention are illustrated below by means of a detailed description and explanation of the embodiments shown in Figures 1 to 7. These show, specifically:

Figure 1: a top view of an outer side of a first embodiment of a textile substrate according to the invention, consisting of threads of three materials,

Figure 2: a top view of an outer side of a second embodiment of a textile substrate according to the invention, consisting of threads of three materials,

Figure 3: a top view of an outer side of a third embodiment of a textile substrate according to the invention, consisting of threads of three materials,

Figure 4: a top view of an outer side of a fourth embodiment of a textile substrate according to the invention, consisting of threads of three materials,

Figure 5: top views of an outer side of a fifth embodiment of a textile substrate according to the invention (left-hand half), consisting of threads of three materials, and a view following the destruction and removal of the third threads formed from a destructible material of the third material group (right-hand half).

Figure 6: top views of an outer side of a sixth embodiment of a textile substrate according to the invention (left-hand half), consisting of threads of three materials, and the view following the destruction and removal of the third threads formed from a destructible material of the third material group (right-hand half).

Figure 7: top views of an outer side of a seventh embodiment of a textile substrate according to the invention (left-hand half), consisting of threads of three materials, and a view following the destruction and removal of the third threads formed from a destructible material of the third material group (right-hand half).

Detailed description of exemplary embodiments

Unless otherwise stated, the same reference signs are used for the same elements in the figures.

Figure 1 shows a ‘float’ type knitting pattern, in which the visible outer side is defined as the front of the textile substrate 1 and the invisible, opposite outer side as the back thereof. This figure illustrates the arrangement comprising first threads 2, second threads 3 and third threads 4 from three different material groups, which are strategically positioned to create a structure that meets the specific requirements of this invention.

The first threads 2, formed from one or more (first) materials 20 of a first material group, are shown on the front side of the textile substrate 1 without any filling, causing them to appear as white threads. The second threads 3, formed from one or more (second) materials 30 of a second material group, are visualised by a black hatched pattern and positioned in the central plane. The third threads 4, formed from a destructible material 40 of a third material group consisting of destructible materials, are depicted with a solid grey fill and arranged such that they wrap around the front and back of the textile substrate 1, thereby connecting the first threads 2 of the first material group with the second threads 3 of the second material group.

It is assumed here that the first threads 2 and the second threads 3 can be utilised in different ways, and that the destructible material 40 of the third material group can be destroyed by means of a chemical and/or physical process without the chemical and/or physical process structurally impairing the first threads 2 and the second threads 4.

As indicated in Fig. 1, in at least one region B (a corresponding region B is represented in Fig. 1 by a rectangle shown with dotted lines) of the textile substrate 1, a connection between first threads 2 and second threads 3 is realised, by arranging at least one of the third threads 4 in the at least one region B of the textile substrate 1 in such a way that the at least one of the third threads 4 in the at least one region B spatially connects first threads 2 and second threads 3 in that the at least one third thread 4 in the at least one region B crosses one or more first threads 2 and one or more second threads 3 alternately, so that the connection between the first threads 2 and the second threads 3 in the at least one region B is realised exclusively by the at least one of the third threads 4.

According to the invention, it is the third threads 4 of the third material group that play a decisive functional role. They spatially connect the first threads 2 of the first material group with the second threads 3 of the second material group, without any interlacing occurring between the first threads 2 of the first material group and the second threads 3 of the second material group. This specific arrangement ensures that the first threads 2 of the first material group and the second threads 3 of the second material group remain physically separate, which simplifies their individual separation and recycling following the destruction of the third threads 4 of the third material group.

The aforementioned positioning and functionality of these third threads 4 of the third material group not only enables the efficient separation and recycling of the materials 20, 30 of the first and second material groups, but are also essential for sustainable textile production.

This spatial configuration fulfils the technical requirements of the present invention and, at the same time, demonstrates an innovative application of the ‘float’ knitting technique, which aims to meet environmental standards and increase production efficiency.

Figure 2 illustrates a textile substrate 1, produced using the ‘spacer’ knitting technique. This technique enables the creation of a three-dimensional textile with a defined spatial structure, resulting in increased thickness and improved thermal and acoustic insulation properties. The textile substrate again consists of three groups of threads, formed from different materials 20, 30, 40. The first group of first threads 2 formed from a first material 20 of a first material group, and the second group of second threads 3 formed from a second material 30 of a second material group, are configured to form specific patterns or structures designed to meet particular functional or aesthetic requirements.

The third group of third threads 4 consists of a specially formulated, destructible material 40 of a third material group. These third threads 4 are crucial to the structural integrity of the textile substrate 1, as they spatially interconnect the first threads 2 of the first material group and the second threads 3 of the second material group without any interlacing between the first threads 2 and the second threads 3. In doing so, they cross over the first threads 2 of the first material group on one outer side (front) of the textile substrate 1 and the second threads 3 of the second material group on the opposite outer side (back). This arrangement allows the materials to be easily separated for recycling purposes.

As indicated in Fig. 2, in at least one region B (a corresponding region B is represented in Fig. 2 by a rectangle shown with dotted lines) of the textile substrate 1, a connection between the first threads 2 and the second threads 3 is realised in that at least one of the third threads 4 is arranged in the at least one region B of the textile substrate 1 in such a way that the at least one of the third threads 4 in the at least one region B spatially connects first threads 2 and second threads 3 in that the at least one third thread 4 in the at least one region B crosses one or more first threads 2 and one or more second threads 3 alternately, so that the connection between the first threads 2 and the second threads 3 in the at least one region B is realised exclusively by the at least one of the third threads 4.

The third threads 4 of the third material group are integrated into the textile substrate 1 in such a way that they are arranged transversely to the threads 2, 3 of the first and second material groups. This supports the structural integrity of the textile substrate 1 and enables the materials 20, 30 to be separated in an uncomplicated manner without structural damage to the first threads 2 and the second threads 3 during a recycling process.

Figure 3 illustrates an innovative knitted fabric produced using the weft-knitting technique. This textile substrate 1 is again composed of three different material groups, which are strategically positioned to meet specific functional requirements. The use of these three material types supports both structural integrity and sustainability through improved recyclability of the end product.

The first group of first threads 2 consists of a first material 20 of a first material group and appears in Figure 3 as white threads without a fill. These first threads 2 form the basis of the textile substrate 1 and have been selected for their properties such as strength, flexibility and colour fastness, which make them particularly suitable for the basic structure of the knitted fabric.

The second group of second threads 3, shown as horizontally running threads with a diagonally hatched fill, are formed from a second material 30 of a second material group, which differs of the first material 20. This arrangement is intended to enhance certain functional or aesthetic characteristics of the textile substrate 1. These second threads 3 can act as reinforcing elements, introducing additional structural or decorative aspects into the knitted fabric.

The third and decisive group of third threads 4 is formed from a destructible material 40 of a third material group, which can be destroyed by chemical and/or physical processes. These third threads 4 are shown in Figure 3 with a solid grey fill and a thick black outline, and they cross both the first threads 2 of the first material group and the second threads 3 of the second material group at the opposite outer sides of the textile substrate 1. This specific arrangement makes it possible to spatially connect the threads 2, 3 of the first and second material groups without any interlacing between them. This is crucial for structural integrity and facilitates the separation of the materials 20, 30 for recycling purposes.

As indicated in Fig. 3, in at least one region B (a corresponding region B is represented in Fig. 3 by a rectangle shown with dotted lines) of the textile substrate 1, a connection between first threads 2 and second threads 3 is realised in that at least one of the third threads 4 is arranged in the at least one region B of the textile substrate 1 such that the at least one of the third threads 4 in the at least one region B spatially connects first threads 2 and second threads 3 in that the at least one third thread 4 in the at least one region B crosses one or more first threads 2 and one or more second threads 3 alternately, so that the connection between the first threads 2 and the second threads 3 in the at least one region B is achieved

exclusively by the at least one of the third threads 4.

In summary, Figure 3 illustrates a well-thought-out combination of materials 20, 30, 40 and knitting techniques, aimed at creating a highly functional textile that is both aesthetically pleasing and environmentally friendly. The use of biodegradable material 40 in a key position underlines the commitment to sustainable production practices by facilitating the subsequent separation and recycling of the materials 20, 30.

Figure 4 shows a textile substrate 1 produced using the ‘Sweat’ weft-knitting technique, in which various threads 2, 3, 4 formed from at least three different materials 20, 30, 40 are used. These threads 2, 3, 4 comprise a first group of first threads 2 formed from a first material 20 of a first material group, a second group of second threads 3 formed from a second material 30 of a second material group, and a third group of third threads 4 formed from a destructible material 40 of a third material group, wherein the destructible material 30 or each third thread 4 serves as a ‘textile screw’ to hold the other threads 2, 3 together.

The destructible material 40 of the third material group is designed such that it can be destroyed by specific chemical and/or physical processes, thereby enabling the separation and recycling of the materials 20, 30 of the first and second material groups. The third threads 4 of the third material group are arranged within a defined region of the textile substrate 1 in such a way that they spatially connect the threads 2, 3 of the first and second material groups without any interlacing between the first threads 2 and the third threads 3. This ensures the structural integrity of the textile substrate 1, whilst guaranteeing the easy separation of the materials 20, 30 during a recycling process.

As indicated in Fig. 4, in at least one region B (a corresponding region B is represented in Fig. 4 by a rectangle shown with dotted lines) of the textile substrate 1, a connection between first threads 2 and second threads 3 is realised in that at least one of the third threads 4 is arranged in the at least one region B of the textile substrate 1 such that the at least one of the third threads 4 in the at least one region B spatially connects first threads 2 and second threads 3 in that the at least one third thread 4 in the at least one region B crosses one or more first threads 2 and one or more second threads 3 alternately, so that the connection between the first threads 2 and the second threads 3 in the at least one region B is realised exclusively by the at least one of the third threads 4.

The ‘Sweat’ technique shown in Figure 4 creates a structure suitable for clothing, interior furnishings and technical applications in which the subsequent separation and recycling of material components is required. The specific arrangement and selection of materials 20, 30, 40 are designed to optimise the functional and aesthetic properties of the textile substrate 1 whilst, at the same time, enabling circular material flows through the separability.

Figure 5 shows a warp-knitted fabric. The illustration on the left-hand side of Figure 5 depicts a textile substrate 1 composed of threads formed from two different materials 20, 30, and joined by the third, destructible material 40.

In the embodiment (knitting with an insert including a ‘textile screw’) shown in the left-hand half of Figure 5, the first threads 2 formed from the first material 20 of a first material group and the third threads 4 formed from the destructible third material 40 of a third material group utilise the warp-knitting technique and are connected to one another via knitted stitches. Between these threads 2 and 4, second threads 3 formed from the second material 30 of a second material group are integrated in the weft direction. A third thread 4 formed from the destructible third material 40 (“textile screw”) connects two adjacent stitches formed from the first material 20 in each case, creating a robust connection between the materials 20 and 30 and reinforcing the structural integrity of the warp-knitted fabric. This configuration facilitates the subsequent separation and recycling of the materials 20, 30, as the destruction of the destructible material 40 allows for easy separation of the threads 2, 3 formed from the first and second materials 20, 30.

As indicated in Fig. 5, in at least one region B (a corresponding region B is represented in Fig. 5 by a rectangle shown with dotted lines) of the textile substrate 1, a connection between first threads 2 and second threads 3 is realised in that at least one of the third threads 4 is arranged in the at least one region B of the textile substrate 1 in such a way that the at least one of the third threads 4 in the at least one region B spatially connects first threads 2 and second threads 3 in that the at least one third thread 4 in the at least one region B crosses one or more first threads 2 and one or more second threads 3 alternately, so that the connection between the first threads 2 and the second threads 3 in the at least one region B is realised exclusively by the at least one of the third threads 4.

The right-hand half of Figure 5 shows the materials 20, 30 following the removal of material 40 and illustrates the ‘design for disassembly’.

Figure 6 illustrates a biaxial warp-knitted fabric, which is also characterised by the use of a

destructible material 40 of a third material group, referred to here as a ‘textile screw’. The left-hand illustration demonstrates the use of the ‘textile screw’, which incorporates the first threads 2 of the first material 20 of a first material group, also in the warp direction. Between these stitches, which are formed between the first threads 2 of the first material group and third threads 4 formed from the destructible material 40 of the third material group, second threads 3 formed from the second material 30 of a second material group are incorporated in the weft direction. This configuration ensures that, following the destruction of the destructible material 40, the materials 20 remain as a flat surface area and the materials 30 as loose threads, unconnected to one another, which allows for easy separation of the first threads 2 from the second threads 3. The left-hand side of Figure 6 also illustrates how the integration of the ‘textile screw’ improves the structural integrity of the warp-knitted fabric whilst simultaneously being useful for applications requiring subsequent separation and recycling of the materials 20 and 30.

As indicated in Fig. 6, in at least one region B (a corresponding region B is represented in Fig. 6 by a rectangle shown with dotted lines) of the textile substrate 1, a connection is formed between first threads 2 and second threads 3, by arranging at least one of the third threads 4 in the at least one region B of the textile substrate 1 such that the at least one of the third threads 4 in the at least one region B spatially connects first threads 2 and second threads 3 in that the at least one third thread 4 in the at least one region B crosses one or more first threads 2 and one or more second threads 3 alternately, so that the connection between the first threads 2 and the second threads 3 in the at least one region B is realised exclusively by the at least one of the third threads 4.

The right-hand half of Figure 6 shows the materials 20, 30 – following the removal of material 40 – and illustrates the ‘design for disassembly’.

Figure 7 also presents a warp-knitted fabric distinguished by the use of a destructible material 40 as a structure-influencing element. In the left-hand illustration, this ‘textile screw’ serves as a connecting link between first threads 2 formed from a first material 20 of a first material group and second threads 3 formed from a second material 30 of a second material group. Here, the first threads 2 formed from the first material 20 run in the warp direction and are connected, through knitting, to third threads 4 formed from the destructible material 40 via specially formed stitches. In between, second threads 3 formed from the second material 30 are embedded in the weft direction, allowing the materials 20 and 30 to be easily separated once the third material 40 has been destroyed. This structure is designed to enable

straightforward separation of the materials 20 and 30 after use, which is an important requirement for recycling processes.

As indicated in Fig. 7, in at least one region B (a corresponding region B is represented in Fig. 7 by a rectangle shown with dotted lines) of the textile substrate 1, a connection is formed between first threads 2 and second threads 3 in that at least one of the third threads 4 is arranged in the at least one region B of the textile substrate 1 in such a way that the at least one of the third threads 4 in the at least one region B spatially connects first threads 2 and second threads 3 in that the at least one third thread 4 in the at least one region B crosses one or more first threads 2 and one or more second threads 3 alternately, so that the connection between the first threads 2 and the second threads 3 in the at least one region B is realised exclusively by the at least one of the third threads 4.

The right-hand half of Figure 7 shows the materials 20, 30 – following the removal of material 40 – and illustrates the ‘design for disassembly’.

In addition, Figures 1–7 include coatings in the textile substrate 1 that are not shown, which are compatible with the materials 20, 30, 40 and provide specific physical barriers against water, UV radiation and microbial effects. These treatments improve physical properties such as tear strength and shrinkage resistance. The coatings and treatments applied to textile substrate 1 are compatible with the materials of the three thread or material groups and do not impair their separability or recyclability.

In conclusion, it should be noted that the innovative integration of the ‘textile screw’ into the textile substrate 1, consisting of materials 20, 30 and 40, offers both functional and environmental benefits. Functionally, the targeted arrangement of these materials – wherein the first material 20 (e.g. cotton), due to its skin-friendly properties, is placed closer to the body and the second material 30 (e.g. polyamide) on the outer side facing away from the body – enables optimal utilisation of the textile properties. The ‘textile screw’, for example, formed from a hydrophilic material such as polyvinyl alcohol, not only promotes moisture exchange between the layers, thereby increasing wearing comfort, but also improves technical properties such as the product’s durability.

From an environmental perspective, the invention enables separation by material type at the end of the product’s life, thereby facilitating efficient recycling. The economically attractive ‘revenue stream’ generated by this separation by material type significantly improves the sustainability of the product.

The destruction of the ‘textile screw’ thread system results in a significant reduction in thread density within the remaining materials and surface areas, in some cases even allowing the threads to be reduced to just 2 or 3 individual threads. The reduced density facilitates the subsequent processing of the materials to be recycled, such as tearing and carding, for the production of new yarns. The proportion of short fibres is reduced, whilst the quality and quantity of recycled fibres increase.

The introduction of this technology not only promotes environmentally friendly production practices, but also ensures compliance with regulatory requirements, such as those set out in the EU’s Green Deal. These measures make a significant contribution to reducing textile waste and promote recycling in the textile industry.

List of reference signs

1 textile substrate

2 first threads

3 second threads

4 third threads

20 first material of the first material group

30 second material of the second material group

40 destructible material of the third material group

B region of the textile substrate 1

Claims

1. A textile substrate (1), formed as a knitted fabric, produced by means of a weft and/or warp knitting technique, comprising:

first threads (2), each of which is formed from one or more materials (20) of a first material group;

second threads (3), each of which is formed from one or more materials (30) of a second material group; and

third threads (4), each formed from a destructible material (40) of a third material group, which is destructible by means of a chemical and/or physical process;

wherein the first threads (2) and the second threads (3) are variously utilisable;

wherein, in at least one region (B) of the textile substrate (1), a connection between the first threads (2) and the second threads (3) is realised by arranging at least one of the third threads (4) in the at least one region (B) of the textile substrate (1) such that the at least one of the third threads (4) in the at least one region (B) spatially connects first threads (2) and second threads (3) in that the at least one third thread (4) in the at least one region (B) crosses one or more first threads (2) and one or more second threads (3) alternately, so that the connection between the first threads (2) and the second threads (3) in the at least one region (B) is realised exclusively by the at least one of the third threads (4).

2. The textile substrate (1) according to claim 1, wherein the first threads (2) and the second threads (3) are arranged in a defined pattern designed to enable specific functional and/or aesthetic properties of the textile substrate (1).

3. The textile substrate (1) according to claim 1 or 2, wherein the destructible material (40) of the third material group consists of a specially formulated polymer which is destructible upon specific exposure to temperature, pressure, UV light, chemicals, moisture, in an aqueous medium, and in a combination of the aforementioned factors.

4. The textile substrate (1) according to claim 3, wherein the destructible material (40) of the third material group consists of a specially formulated polymer which is

biodegradable.

5. The textile substrate (1) according to claim 3, wherein, following the destruction of the destructible material (40) of the third material group by means of the chemical and/or physical process, the specially formulated polymer adheres to the first threads (2) and/or the second threads (3) as a polymer film, thereby increasing the strength of the first threads (2) and/or the second threads (3).

6. The textile substrate (1) according to any one of preceding claims 1 to 5, wherein the textile substrate (1) additionally comprises layers or coatings which are such that they are compatible with the materials (20, 30, 40) of the first, second and third material groups and do not impair their separability or recyclability, and wherein these layers or coatings provide specific physical barriers against water, UV radiation and/or microbial impacts.

7. The textile substrate (1) according to any one of preceding claims 1 to 5, wherein the third threads (4) are integrated into the textile substrate (1) in such a way that they are arranged transversely to the second threads (2) and the third threads (3), and thus, by virtue of their spatial arrangement, support the structural integrity of the textile substrate (1) during use, wherein the arrangement of the third threads (3) facilitates an easy separation of the first threads (2) from the second threads (3) or an easy separation of the materials (20) of the first material group from the materials (30) of the second material group following the destruction of the destructible material (40) of the third material group, without causing structural damage to the first threads (2) and the second threads (3) during a recycling process.

8. The textile substrate (1) according to any one of preceding claims 1 to 7, which has been subjected to a post-treatment, such as calendering or a permanent silicone coating, in order to improve physical properties, such as tear strength, colour fastness and/or shrink resistance, of the textile substrate (1) without impairing the recyclability of the textile substrate (1).

9. Use of a textile substrate (1) according to any one of preceding claims 1 to 8 for all types

of knitted fabrics, such as clothing, interior furnishings or technical applications, which allow for the subsequent separation and recycling of material components.

10. A method for processing a textile substrate (1) according to any one of claims 1 to 8, comprising the steps of:

a) applying a chemical and/or physical process to destroy the destructible material (40) of the third threads (4),

b) mechanically separating the first threads (2) from the second threads (3) without causing any structural damage to these threads (2, 3), and

c) collecting the separated threads (2, 3) for recycling, wherein the destruction of the destructible material (40) takes place in such a way that the specific spatial arrangement of the third threads (4) enables the first threads (2) to be spatially separated from the second threads (3).