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(71) Applicant: **Beaulieu International Group NV**
8790 Waregem (BE)

(72) Inventors:
- **LEYS, Michiel**
  9850 Deinze (BE)
- **SINNAEVE, Anthony**
  59153 Grand-Fort-Philippe (FR)

(74) Representative: **De Clercq & Partners**
Edgard Gevaertdreef 10a
9830 Sint-Martens-Latem (BE)

(54) **YARNS FOR FLOOR COVERINGS AND METHODS FOR PRODUCING YARNS**

(57) The present invention in general relates to yarns having variable properties along the length of the yarn, and methods and apparatuses for producing such yarns.

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Description

TECHNICAL FIELD

[0001] The present invention in general relates to yarns for floor coverings, the yarns having variable properties along the length of the yarn, and methods and apparatuses for producing such yarns.

BACKGROUND

[0002] Nowadays, the manufacture of carpets is the result of a well-established process based on a coupled process "shaped yarns - tufting process". The yarns are typically polyamide yarns which are shaped and then implemented on tufting machines. It should be noted that compared to weaving, tufting involves the implementation of a support on which the yarns will be tufted.

[0003] A main objective in the carpet industry is to be able to obtain carpets with a design that is defined by variations in colours and thicknesses that result in a design that can be more or less sophisticated. It should be noted that there are two main types of carpet finishes:

- loop finishes, as they come out of the tufting process;
- cut finishes, for which the loops are cut to produce a velvet-like appearance; and,
- cut loop finishes, for which the highest loops are cut to create the design.

[0004] The carpet industry is increasingly structured according to two segments:

- large series products, structured according to a competitive strategy of the type "volume - price" (such as the residential market); and,
- products of small and medium series which are customized according to targets specific markets (such as architects, small series for specific customers of the type hotel - office, herein also referred to as the "contract market")

[0005] Beyond the quality of the rug, the main means of differentiation is the level of design. At this level, there are two main types of process:

1) A process using raw white polyamide yarns, which are printed after the tufting operations, may be performed in two ways: a continuous process comparable to screen printing, or a process using digital printing. However, the quality of the end-products remains limited: these are essentially large series products targeting low-midrange "volume/price" type segments, with limited reproducibility, and above all poor wear resistance (problem of discoloration of the carpet following cleaning). These technologies are not suitable for small and medium qualitative series. A more qualitative product may be obtained via digital printing, but the latter becomes very expensive. In addition, the technology via screen printing type is very polluting (significant consumption of water, dyes, problems of effluents to be treated).

2) A process using polyamide threads dyed in the mass, which can have a variable degree of shaping. In this case, the yarns may be shaped according to two main types of process:

- twisting processes, with, for example, in the case of mechanically twisted yarns, twists that can vary from 30 to 300 turns per meter, which may include from 1 to 3 threads; and,
- entangling processes, during which the threads are mixed, with the mixture being fixed by knots created by punctual pressures of high pressure compressed air. These nodes can have configurable frequencies, but with fixed sequences by implementing 1 to 6 yarns.

[0006] By combining these two technologies, a very wide variety of yarns can be obtained in terms of colours, contrast, appearance, and texture. However, if the nature of the yarn has a basic impact on the design of the carpet, the latter is ultimately generated by the tufting machines, which can present a very high degree of complexity, with the capacity to manage more than 1,600 coils of threads at the same time and the implementation of up to 3 or 4 threads of different types. From these threads, the design may be generated by the machine.

[0007] However, even though it may be really effective, this type of process has many limits:

- The more sophisticated the design of the carpet, the more complex the tufting machine will be in terms of its functionalities, which leads to higher costs (from 400 k€ to 1,600 k€/unit) for both initial investment and maintenance.
- The more sophisticated the design of the carpet, the lower the production speed, and the higher the production costs.
- The large number of spools and types of yarn that may be necessary for the production of these carpets, may lead to high levels of stock in progress and significant losses (unused reels, rework).
- Production launches require significant preparation and fine-tuning times which can take several hours, and which may be prolonger when the design is sophisticated.
- To obtain a given design, this type of process requires a greater quantity of material than regular tufting, with differences that may be of the order of 20%.
- The design is typically generated by differences in thickness, which leads to weaker spots that are more susceptible to wear and tear for the same average thickness.

[0008] Therefore, there are significant limits in the ability to produce carpets having sophisticated designs, and especially the virtual impossibility of producing small and medium series of carpets having sophisticated designs under satisfactory industrial and economic conditions.

[0009] In conclusion, the existing technologies are only suited to mass production with a limited level of design quality (residential market), but respond poorly to the contract market (e.g., public buildings, architectural projects, hotels), consisting of small and medium series with a specific level of design and high quality.

[0010] Therefore, there is a need for new methods that overcome one or more of the aforementioned disadvantages.

SUMMARY OF THE INVENTION

[0011] The present invention solves one or more of the aforementioned problems, by providing a yarn that has become "programmable". The design of the carpet would be generated automatically by the simple tufting of the yarns. Thus, these yarns would be shaped in a specific way to be able to generate the desired design as the tufting operation progresses. Sophisticated design carpet manufacturing operations could be carried out from simple and inexpensive tufting machines, since the latter would no longer have to generate sophisticated designs made from several types of spools of yarn. This makes it possible to solve a large part of the problems encountered in obtaining contract products in small and medium series with a high design level.

[0012] Preferably, the invention solves this problem by varying the colour contrast from 2 up to 6 yarn ends by randomly varying the yarn tension of each individual yarn end individually or in combination following two axes of variation (absolute value tension and duration of constant tension). The yarn may then be used in a standard level loop-pile carpet. In some embodiments, the sections of the yarn are produced in such a way that a defined yarn pattern of variation can be repeated and can be developed to match with a specific carpet design.

[0013] The invention, and (preferred) embodiments thereof, may have one or more of the following advantages. It allows the possibility to produce floor coverings, such as carpets, rugs, and artificial turfs:

- with (more) complex designs yet still using standard straightforward tufting machines.
- with (more) complex designs at a lower complexity of operations and machinery.
- with (more) complex designs at a lower cost of operations and machinery.
- with (more) complex designs with a lower pile weight.
- with (more) complex designs with improved resilience.
- with (more) complex designs at an increased efficiency.
- with (more) complex designs with less waste.
- with (more) complex designs with an easier supply chain.

[0014] In a first aspect, the present invention provides a method for producing a yarn with variable properties along the length of the yarn. The method preferably comprises the steps of:

a. providing M yarns through M yarn feeders, wherein M is at least 2; and,
b. providing an apparatus comprising an air-entanglement and/or air-twisting unit and M individually controllable valves, configured for feeding the M yarns into the air-entanglement and/or air-twisting unit under a set pressure.

[0015] The method preferably comprises N stages; wherein each stage n ranging from 1 to N has a time duration Δt_n. Each stage n ranging from 1 to N preferably comprises one or more, preferably all, of the steps of:

i. feeding each of the M yarns into each of the M valves to obtain a bundle of M tensioned twisted yarns, preferably wherein each yarn m of the M yarns is twisted under a variable Valve Parameter Set VP (VP_1n, ..., VP_Mn) defined by each valve m of the M valves, depending on the yarn m and depending on the stage n; wherein each stage n may differ in at least one Valve Parameter from the previous stage n-1; and,
ii. optionally, feeding the bundle of M tensioned twisted yarns to an air-tack unit to fix them as a bundle defined by the Valve Parameter Set VP1 (VP1_1n, ..., VP1_Mn) and/or feeding the bundle of M tensioned twisted yarns to an air-entanglement unit to over-entangle the bundle of twisted yarns defined by the Valve Parameter Set VP2 (VP2_1n, ..., VP2_Mn) of said stage n; wherein each stage n may differ in at least one Valve Parameter from the previous stage n-1.

Preferably, VP, VP1, and VP2 are all different settings.

[0016] The method according to the first aspect of the invention thereby obtains a yarn comprising multiple sections with variable properties along the length of the yarn.

[0017] As used herein, the Valve Parameter Set VP preferably refers to the pressure for obtaining M twisted yarn. As used herein, the Valve Parameter Set VP1 preferably refers to the pressure of an air-tack unit to obtain a tacked bundle of twisted yarn. As used herein, the Valve Parameter Set VP2 preferably refers to the pressure of an air-entanglement unit to obtain an over-entangled bundle of twisted yarn.

[0018] In some preferred embodiments, at least 2 of the M yarns differ in at least one property parameter, preferably all of the M yarns differ in at least one property parameter. Preferably, at least 2 of the M yarns, preferably all of the M yarns, differ in at least one of following

property parameters: colour, thickness, material, number of filaments, shape of filaments. Most preferably, at least 2 of the M yarns, preferably all of the M yarns, differ in colour.

[0019] In some preferred embodiments, M is at least 3, preferably at least 4, for example at most 8, for example at most 6.

[0020] In some preferred embodiments, N is at least 10, for example at least 50. The value of N may be fixed or randomized. Each stage may be fixed or randomized.

[0021] In some preferred embodiments, each valve of the M valves is a twist jet. Preferably there are 6 valves for Air-Twist jet. Preferably there is 1 valve for both Air-Tack & Air Entanglement. In some preferred embodiments, the Valve Parameter is related to the pressure valve setting of each valve m ranging from 1 to M. Preferably the variable Valve Parameter VP comprises the feeding pressure of each valve m of the M valves to the air-entanglement (VP2) and/or air-tack (VP1) unit for each yarn m of the M yarns. In some preferred embodiments, the feeding pressure may be varied between 0.0 and 3.5 bar, preferably for VP. In some preferred embodiments, the feeding pressure may be varied between 0.0 to 9.0 bar, preferably for VP1 and/or VP2.

[0022] Preferably, the VP (preferably corresponding to an Air-Twist) valves can be set individually for each yarn m of the M yarns. Preferably, there are up to 6 such valves. Preferably, the VP1 and VP2 (preferably corresponding to an Air-Tack and Air Entanglement) valves can be set for the bundle of yarns. Preferably, there are at least 2 and at most 6 yarns in the bundle of yarns.

[0023] In some preferred embodiments, the method further comprises the steps of:

c. providing, preferably by a computer program product, an MxN input matrix of Valve Parameters VP (VP_11, ..., VP_MN) and/or of Valve Parameters VP1 (VP1_11, ..., VP_MN) and/or of Valve Parameters VP2 (VP2_11, ..., VP_MN) to the apparatus;

and automatically operating the apparatus based on the MxN input matrix.

[0024] In some preferred embodiments, the air-entanglement and/or air-twisting unit operates at a pressure in the range of at least 1 bar and at most 20 bar, more preferably at least 2 bar and at most 15 bar, and even more preferably at least 4 bar and at most 12 bar, most preferably at least 7 and at most 10 bar.

[0025] In some preferred embodiments, the time duration Δt_n for each stage 1 to N is at least 0.05 s and at most 20.0 s.

[0026] In some preferred embodiments, the M yarns are Bulk Continuous Filament (BCF) and/ or Continuous Multifilament (CF) yarns.

[0027] In some preferred embodiments, the M yarns have a linear density of at least 150 dtex and at most 3000 dtex, for example at least 300 dtex and at most 1400 dtex, preferably at least 400 dtex and at most 1000 dtex, preferably at least 500 dtex and at most 800 dtex, preferably at least 600 dtex and at most 700 dtex, for example about 650 dtex.

[0028] In a second aspect, the present invention provides a computer program or a computer-readable storage medium comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method according to the first aspect of the invention, or (preferred) embodiments thereof.

[0029] (Preferred) embodiments of the first aspect of the invention are also (preferred) embodiments of the second aspect of the invention, and vice versa.

[0030] In a third aspect, the present invention provides a yarn with variable properties along the length of the yarn, produced by the method according to the first aspect of the invention, or (preferred) embodiments thereof.

[0031] (Preferred) embodiments of the first aspect of the invention are also (preferred) embodiments of the third aspect of the invention, and vice versa.

[0032] In a fourth aspect, the present invention provides a method for producing a floor covering, such as a carpet, a rug, or an artificial turf, with a variable design on the surface of a floor covering. The method preferably comprises one or more, preferably all, of the steps of:

- performing the method according to the first aspect of the invention, or (preferred) embodiments thereof, to provide a yarn with variable properties along the length of the yarn; and,
- tufting a floor covering, such as carpet, rug, or artificial turf, with the provided yarn with variable properties along the length of the yarn.

[0033] The method according to the fourth aspect of the invention thereby produces a floor covering, such as a carpet, rug, or artificial turf, with a variable design on the surface.

[0034] In a fifth aspect, the present invention provides a floor covering, such as a carpet, a rug, or an artificial turf, with a variable design on the surface of the floor covering, produced by the method according to the fourth aspect of the invention, or (preferred) embodiments thereof.

[0035] (Preferred) embodiments of the first or third aspect of the invention are also (preferred) embodiments of the fourth or fifth aspect of the invention, and vice versa.

[0036] The independent and dependent claims set out particular and preferred features of the invention. Features from the dependent claims may be combined with features of the independent or other dependent claims as appropriate.

[0037] The present invention will now be further described. In the following passages, different aspects of the invention are defined in more detail. Each aspect so defined may be combined with any other aspect or aspects unless clearly indicated to the contrary. In particular, any feature indicated as being preferred or advantageous may be combined with any other feature or features indicated as being preferred or advantageous.

DETAILED DESCRIPTION OF THE FIGURES

[0038]

FIG. 1 illustrates an embodiment of an apparatus (100) and method according to the invention.

FIG.2 and **FIG.3** and **FIG.4** illustrates close-ups of various features of different types of an apparatus (100) according to an embodiment of the invention. **FIG. 2A** illustrates a helicopter view close-up of an air-twisting unit (60) according to an embodiment of the invention. **FIG. 2B** illustrates a zoomed in view demonstrating how yarns (10) are fed to the tack unit (62). **FIG. 2C** illustrates an air valve twist unit (64) in detail. **FIG. 3A** illustrates a close-up of a yarn tension sensor (86) according to an embodiment of the invention. **FIG. 3B** illustrates a helicopter view of a yarn tension sensor (86) to show the device in perspective within the overall process. **FIG. 4A** illustrates a close-up of an automatic tensioner (84) according to an embodiment of the invention. **FIG. 4B** illustrates a helicopter view an automatic tensioner (84) to show the device in perspective within the overall process.

FIG. 5A illustrates a level loop-pile carpets tufted with a yarn (1) according to an embodiment of the invention. **FIG. 5B (left)** and **FIG. 5C (left)** illustrate structure loop-pile carpets not tufted with a yarn according to an embodiment of the invention. **FIG. 5B (right)** and **FIG. 5C (right)** illustrate level loop-pile carpets tufted with a yarn (1) according to an embodiment of the invention.

FIG. 6 illustrates simplified representation of an intermingling process taking place in an air-entanglement and/or air-twisting unit (60) according to an embodiment of the invention.

FIG. 7 illustrates an example to illustrate the invention. Each grey scale corresponds to a different twist level, for M=6 yarns.

[0039] The following numbering will be adhered to in the figures:

(1) yarn with variable properties along the length of the yarn
(100) yarn entanglement apparatus
(10) yarns, from 2 .. M
(15) textured yarn
(16) intermingled yarn
(17) interlacing points
(20) yarn feeders, from 2 .. M
(22) overfeed rolls
(60) air-entanglement and/or air-twisting unit
(61) compressed air inlet
(62) tack jet
(64) twist jet
(82) creel tensioner
(84) automatic tensioner
(86) yarn tension sensor

DETAILED DESCRIPTION OF THE INVENTION

[0040] When describing the invention, the terms used are to be construed in accordance with the following definitions, unless a context dictates otherwise.

[0041] As used herein, the singular forms "a", "an", and "the" include both singular and plural referents unless the context clearly dictates otherwise. By way of example, "a resin" means one resin or more than one resin.

[0042] The terms "comprising", "comprises" and "comprised of" as used herein are synonymous with "including", "includes" or "containing", "contains", and are inclusive or open-ended and do not exclude additional, non-recited members, elements, or method steps. It will be appreciated that the terms "comprising", "comprises" and "comprised of" as used herein comprise the terms "consisting of", "consists" and "consists of".

[0043] The recitation of numerical ranges by endpoints includes all integer numbers and, where appropriate, fractions subsumed within that range (e.g. 1 to 5 can include 1, 2, 3, 4 when referring to, for example, a number of elements, and can also include 1.5, 2, 2.75 and 3.80, when referring to, for example, measurements). The recitation of end points also includes the end point values themselves (e.g. from 1.0 to 5.0 includes both 1.0 and 5.0). Any numerical range recited herein is intended to include all sub-ranges subsumed therein.

[0044] All references cited in the present specification are hereby incorporated by reference in their entirety. In particular, the teachings of all references herein specifically referred to are incorporated by reference.

[0045] Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as would be apparent to a person skilled in the art from this disclosure, in one or more embodiments. Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art.

[0046] The terms described above and others used in the specification are well understood to those skilled in the art.

[0047] Preferred statements (features) and embodiments, resins and uses of this invention are set herein below. Each statement and embodiment of the invention so defined may be combined with any other statement and/or embodiment unless clearly indicated to the contrary. In particular, any feature indicated as being preferred or advantageous may be combined with any other feature or features or statements indicated as being preferred or advantageous. Hereto, the present invention is in particular captured by any one or any combination of one or more of the below numbered aspects and embodiments, with any other statement and/or embodiment.

[0048] The independent and dependent claims set out particular and preferred features of the invention. Features from the dependent claims may be combined with features of the independent or other dependent claims as appropriate.

[0049] The present invention will now be further described. In the following passages, different aspects of the invention are defined in more detail. Each aspect so defined may be combined with any other aspect or aspects unless clearly indicated to the contrary. In particular, any feature indicated as being preferred or advantageous may be combined with any other feature or features indicated as being preferred or advantageous.

[0050] In a first aspect, the present invention provides a method for producing a yarn with variable properties along the length of the yarn. The method preferably comprises the steps of:

a. providing M yarns through M yarn feeders, wherein M is at least 2; and,

b. providing an apparatus comprising an air-entanglement and/or air-twisting unit and M individually controllable valves, configured for feeding the M yarns into the air-entanglement and/or air-twisting unit under a set pressure.

The method preferably comprises N stages; wherein each stage n ranging from 1 to N has a time duration Δt_n. Each stage n ranging from 1 to N preferably comprises one or more, preferably all, of the steps of:

i. feeding each of the M yarns into each of the M valves to obtain a bundle of M tensioned twisted yarns, preferably wherein each yarn m of the M yarns is twisted under a variable Valve Parameter Set VP (VP_1n, ..., VP_Mn) defined by each valve m of the M valves, depending on the yarn m and depending on the stage n; wherein each stage n may differ in at least one Valve Parameter from the previous stage n-1; and,

ii. optionally, feeding the bundle of M tensioned twisted yarns to an air-tack unit to fix them as a bundle defined by the Valve Parameter Set VP1 (VP1_1n, ..., VP1_Mn) and/or feeding the bundle of M tensioned twisted yarns to an air-entanglement unit to over-entangle the bundle of twisted yarns defined by the Valve Parameter Set VP2 (VP2_1n, ..., VP2_Mn) of said stage n; wherein each stage n may differ in at least one Valve Parameter from the previous stage n-1.

[0051] The method according to the first aspect of the invention thereby obtains a yarn comprising multiple sections with variable properties along the length of the yarn.

[0052] The method may be continuous or discrete, preferably the method is continuous.

[0053] As used herein, the Valve Parameter Set VP preferably refers to the pressure for obtaining M twisted yarn. As used herein, the Valve Parameter Set VP1 preferably refers to the pressure of an air-tack unit to obtain a tacked bundle of twisted yarn. As used herein, the Valve Parameter Set VP2 preferably refers to the pressure of an air-entanglement unit to obtain an over-entangled bundle of twisted yarn.

[0054] The method preferably comprises the step of providing M yarns, wherein M is at least 2. In some embodiments, the method comprises the step of providing M yarns on M bobbins. The yarns may be monofilament yarns or multi-filament yarns. Each filament may be the same or different. For example, the yarns may be multi-coloured multi-filament yarns.

[0055] In some embodiments, one or more of the M yarns, preferably all of the M yarns, are fed at a speed of at least 100 m/min to at most 1 000 m/min, preferably at least 200 m/min to at most 800 m/min, preferably at least 400 m/min to at most 600 m/min, for example about 500 m/min.

[0056] The method preferably comprises the step of providing M yarns through M yarn feeders, preferably positive yarn feeders, configured for feeding M yarns, wherein M is at least 2. The apparatus preferably comprises M yarn feeders. In some embodiments, the yarn feeders comprise 2 feeding rolls. In some embodiments, the yarn feeders are positive yarn feeders, i.e., they comprise a motor to rotate the feeding rolls, preferably a small electric motor. Such a yarn feeder is an active feeder instead of being a merely passive feeder, and provides controlled feeding of the yarn. The positive yarn feeder ensures that the tension is properly controlled and that the required yarn is in the proper position, for the synchronisation to be properly performed.

[0057] In some embodiments, the apparatus comprises overfeed rolls. These overfeed rolls guarantee an even tension during production, before air-entanglement and/or air-twisting unit.

[0058] The apparatus preferably comprises an air-entanglement and/or air-twisting unit, herein also referred to as entanglement jet or Air-Twist. The yarns may be entangled or twisted, and both terms may be used interchangeably herein. The air-entanglement and/or air-twisting unit may be operated continuously or in discrete burst. Preferably, the air-entanglement and/or air-twisting unit is operated continuously. The air-entanglement and/or air-twisting unit typically has an air-injection feed,

as illustrated in FIG. 7. The air-entanglement and/or air-twisting unit allows for 2 or more yarns to be entangled and form a new yarn.

[0059] In some embodiments, the air-entanglement and/or air-twisting unit comprises a tack jet and/or a twist jet, preferably a twist jet. A tack jet provides a tack point (splice), while a twist jet twists. In some embodiments, a twist jet is preferred, since changing the twist level will create the design. Adding a tack point merely fixes the twisting level.

[0060] The apparatus preferably comprises M individually controllable valves, configured for feeding the M yarns into the air-entanglement and/or air-twisting unit under a set tension. These valves preferably each have a feeding pressure, which can be regulated. For example, an open valve may correspond to a feeding pressure of 3.5 bar (pressure), while a closed valve may correspond to a feeding pressure of 0 bar (no pressure).

[0061] The individual M valves setting point range with a constant tension thanks to tensioner (for example illustrated as 84-86) create a torsion level changing along the M yarns In some embodiments, one or more of the M valves, preferably all of the M valves, are fed at a pressure of at least 0 bar to at most 8 bar, preferably at least 1 bar to at most 6 bar, preferably at least 3 bar to at most 5 bar.

[0062] In some preferred embodiments, each valve of the M valves is a twist jet. In some preferred embodiments, the Valve Parameter is related to the valve setting of each valve m ranging from 1 to M. Preferably the variable Valve Parameter VP comprises the feeding pressure of each valve m of the M valves to the air-entanglement and/or air-twisting unit for each yarn m of the M yarns. In some preferred embodiments, the feeding pressure may be varied between 0 and 3.5 bar.

[0063] In some embodiments, the apparatus comprises a yarn tension sensor, to properly control the tension on each yarn.

[0064] The method preferably comprises N stages, each with a time duration Δt_n.

[0065] Each stage n ranging from 1 to N preferably comprises the step of:

> i. feeding each of the M yarns into each of the M valves to obtain a bundle of M tensioned twisted yarns, preferably wherein each yarn m of the M yarns is twisted under a variable Valve Parameter Set VP (VP_1n, ..., VP_Mn) defined by each valve m of the M valves, depending on the yarn m and depending on the stage n; wherein each stage n may differ in at least one Valve Parameter from the previous stage n-1

[0066] The Valve Parameter is typically indicative for the twist applied to the yarn. The Valve Parameter may be related to yarn count, yarn thread-up, production speed, and air pressure level, preferably air pressure level.

[0067] The yarn twist may be varied randomly. The yarn twist may be varied in a predefined manner. The yarn twist may be varied following two axes of variation, for example the absolute value of the valve pressure level and the duration of constant tension.

[0068] Typically the valve has several discrete settings. The valve latency may be at least 0.01 s and at most 0.15 s, for example at least 0.02 s and at most 0.10 s, for example about 0.05 s.

[0069] Each stage n ranging from 1 to N preferably comprises the step of:

ii. feeding the bundle of M tensioned twisted yarns to an air-tack unit to fix them as a bundle defined by the Valve Parameter Set VP1 (VP1_1n, ..., VP1_Mn) and/or feeding the bundle of M tensioned twisted yarns to an air-entanglement unit to over-entangle the bundle of twisted yarns defined by the Valve Parameter Set VP2 (VP2_1n, ..., VP2_Mn) of said stage n; wherein each stage n may differ in at least one Valve Parameter from the previous stage n-1.

[0070] For example, a first coloured yarn that is twisted loosely will be fed at a greater rate into the air-entanglement and/or air-twisting unit than a second differently-coloured yarn that is twisted tightly. This will result in the colour of the first yarn dominating over the colour of the second yarn. If in a subsequent stage the second yarn is twisted loosely while the first yarn is twisted tightly, the colour of the second yarn will dominate over the colour of the first yarn. This will result in a yarn that comprises sections in variating colours.

[0071] In some embodiments, the twist difference between yarns within one stage may be at least 10%, for example at least 20%, for example at least 50%, for example at least 100%, for example at least 200%. In some embodiments, the twist difference between stages for one yarn may be at least 10%, for example at least 20%, for example at least 50%, for example at least 100%, for example at least 200%.

[0072] In some preferred embodiments, at least 2 of the M yarns differ in at least one property parameter, preferably all of the M yarns differ in at least one property parameter. Preferably, at least 2 of the M yarns, preferably all of the M yarns, differ in at least one of following property parameters: colour, thickness, material, number of filaments, shape of filaments. Most preferably, at least 2 of the M yarns, preferably all of the M yarns, differ in colour and/or colour shade. This allows for a yarn to be produced wherein sections have different colours.

[0073] In some embodiments, some or all yarns differ in colour, and are for example mono- and/or multicolour, ecru, solution dyed (also referred to as dope dyed), and/or bobbin dyed. In some embodiments, some or all yarns differ in yarn count and/or thickness. In some embodiments, some or all yarns differ raw material. In some embodiments, some or all yarns differ in number of filaments and/or filament shape. The other property parameters of each yarn may also be the same or different.

[0074] In some embodiments, two or more of the M

yarns are identical, optionally all are identical. This still allows a yarn to be produced with different sections. For example, the thickness of each section will depend on the number of yarns present in each section.

[0075] The yarns may comprise polyamide (such as nylon), polypropylene, polyethylene, polyester, wool, and/or any other raw material.

[0076] In some preferred embodiments, M is at least 3, preferably at least 4, for example at most 8, for example at most 6.

[0077] In some preferred embodiments, N is at least 10, for example at least 50, for example at least 100. In some embodiments, the length of at least one section, preferably of both sections, produced during each of the N stages is at least 2.0 m, preferably at least 5.0 m, preferably at least 10.0 m. In some embodiments, the length of the change-over section produced during each of the N stages is at least 0.05 m, preferably at least 0.10 m, preferably at least 0.20 m, for example about 0.50 m. The value of N may be fixed or randomized. Each stage may be fixed or randomized.

[0078] In some embodiments, there is repetition between the sections. In some embodiments, there is no repetition between the sections.

[0079] In some preferred embodiments, the Valve Parameter is related to the tensioning setting value of each valve m ranging from 1 to M. Preferably the variable Valve Parameter VP comprises the feeding pressure of each valve m of the M valves to the air-entanglement and/or air-twisting unit for each yarn m of the M yarns.

[0080] In some preferred embodiments, the method further comprises the steps of:

c. providing, preferably by a computer program product, an MxN input matrix of Valve Parameters VP (VP_11, ..., VP_MN) and/or of Valve Parameters VP1 (VP1_11, ..., VP_MN) and/or of Valve Parameters VP2 (VP2_11, ..., VP_MN) to the apparatus;

and automatically operating the apparatus based on the MxN input matrix.

[0081] In some preferred embodiments, the air-entanglement and/or air-twisting unit operates at a pressure in the range of at least 1 bar and at most 20 bar, more preferably at least 2 bar and at most 15 bar, and even more preferably at least 4 bar and at most 12 bar, most preferably at least 7 and at most 10 bar.

[0082] In some preferred embodiments, the time duration Δt_n for each stage 1 to N is at least 0.5 s and at most 20.0 s, for example at least 1.0 s and at most 15.0 s, for example at least 2.0 s and at most 10.0 s.

[0083] In some embodiments, the method further comprises the step of unwinding the M yarns from one or more bobbins, preferably M bobbins, upon which the M yarns were wound prior to being fed to the apparatus.

[0084] In some embodiments, the method further comprises the step of printing the yarn with a yarn printer, preferably before entering the air-entanglement and/or air-twisting unit.

[0085] In some preferred embodiments, the M yarns are Bulk Continuous Filament (BCF) and/ or Continuous Multifilament (CF) yarns. Bulk Continuous Filament is preferred because of its bulk added value for a better carpet coverage.

[0086] In some preferred embodiments, the M yarns have a linear density of at least 150 dtex and at most 3000 dtex, for example at least 300 dtex and at most 1400 dtex, preferably at least 400 dtex and at most 1000 dtex, preferably at least 500 dtex and at most 800 dtex, preferably at least 600 dtex and at most 700 dtex, for example about 650 dtex. Typically, if fewer M is lower, such as 2 or 3, the dtex of the yarns may be in the higher range. Conversely, if M is higher, such as 5 or 6, the dtex of the yarns may be in the lower range. This allows for a suitable yarn to be formed, that is still strong yet can still easily be tufted.

[0087] In some embodiments, the apparatus further comprises one or more bobbins, herein also referred to as feed bobbins, preferably M bobbins, upon which the M yarns are wound prior to being fed to the apparatus.

[0088] In a second aspect, the present invention provides a computer program or a computer-readable storage medium comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method according to the first aspect of the invention, or (preferred) embodiments thereof. The present invention also provides a data processing apparatus/device/system comprising means for carrying out the method according to the first aspect of the invention, or (preferred) embodiments thereof.

[0089] (Preferred) embodiments of the first aspect of the invention are also (preferred) embodiments of the second aspect of the invention, and vice versa.

[0090] In some embodiments, the apparatus as described herein comprises a computer. In some embodiments, the method as described herein is a computer-implemented method.

[0091] In a third aspect, the present invention provides a yarn with variable properties along the length of the yarn, produced by the method according to the first aspect of the invention, or (preferred) embodiments thereof.

[0092] (Preferred) embodiments of the first aspect of the invention are also (preferred) embodiments of the third aspect of the invention, and vice versa.

[0093] In some embodiments, the M yarns have a linear density of at least 150 dtex and at most 3000 dtex, for example at least 300 dtex and at most 1400 dtex, preferably at least 400 dtex and at most 1000 dtex, preferably at least 500 dtex and at most 800 dtex, preferably at least 600 dtex and at most 700 dtex, for example about 650 dtex.

[0094] In some embodiments, the yarn has an average linear density of at least 1300 dtex and at most 10000 dtex, preferably at least 2000 dtex and at most 3200 dtex, wherein the average is calculated over the entire length of the yarn.

[0095] In a fourth aspect, the present invention provides a method for producing a floor covering, such as a

carpet, a rug, or an artificial turf, with a variable design on the surface of a floor covering. The method preferably comprises one or more, preferably all, of the steps of:

- performing the method according to the first aspect of the invention, or (preferred) embodiments thereof, to provide a yarn with variable properties along the length of the yarn; and,
- tufting a floor covering, such as carpet, rug, or artificial turf, with the provided yarn with variable properties along the length of the yarn.

The method according to the fourth aspect of the invention thereby produces a floor covering, such as a carpet, rug, or artificial turf, with a variable design on the surface.

[0096] In a fifth aspect, the present invention provides a floor covering, such as a carpet, a rug, or an artificial turf, with a variable design on the surface of the floor covering, produced by the method according to the fourth aspect of the invention, or (preferred) embodiments thereof.

[0097] (Preferred) embodiments of the first or third aspect of the invention are also (preferred) embodiments of the fourth or fifth aspect of the invention, and vice versa.

[0098] The present invention has the advantage that it allows floor covering manufacturers (such as carpet tufting companies) to create a special design on the floor covering (such as a carpet) while only using standard tufting machinery with the new yarn, instead of having to invest in a more complex and expensive technical tufting machinery.

[0099] In some embodiments, the tufted floor covering may be a looped floor covering. In some embodiments, the tufted loops may be cut. In some embodiments, the tufted floor covering may be a cut loop floor covering.

[0100] Preferably, the floor covering is a level floor covering, such as a level loop-pile carpet. The yarn may be used in a standard level loop-pile carpet. In some embodiments, the sections of the yarn are produced in such a way that a defined yarn pattern of variation can be repeated and can be developed to match with a specific carpet design.

[0101] The present invention also relates to a computer-implemented method that translates the design of a floor covering, such as a carpet, rug, or artificial turf, to the design of the yarn. The present invention also relates to a computer program or a computer-readable storage medium comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method computer-implemented method that translates the design of a floor covering, such as a carpet, rug, or artificial turf, to the design of the yarn.

EXAMPLES

[0102] The following examples serve to merely illustrate the invention and should not be construed as limiting its scope in any way. While the invention has been shown in only some of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes and modifications without departing from the scope of the invention.

[0103] **FIG. 1** illustrates an embodiment of an apparatus (100) and method according to the invention, leading to the final yarn (1). Six yarns (10) are unwound and fed to the apparatus (100). Each yarn (10) A-F is connected to a positive yarn feeder (20) with a feeding speed of 500 m/min. Subsequently, each yarn (10) is connected to a creel tensioner (82) and wound on overfeed roll (22). The yarns (10) subsequently pass an automatic tensioner (84) and a yarn tension sensor (86, before entering the air-entanglement and/or air-twisting unit (60), which entangles the yarns (10). A yarn (1) exits the air-entanglement and/or air-twisting unit (60), and may be fed onto overfeed rolls (22).

[0104] **FIG.2** and **FIG.3** and **FIG.4** illustrates close-ups of various features of different types of an apparatus (100) according to an embodiment of the invention. **FIG. 2A** illustrates a helicopter view close-up of an air-twisting unit (60) according to an embodiment of the invention, thereby illustrating an overall picture of the airt-twisting unit (60) as a block in perspective to demonstrate how the yarn goes through different elements. **FIG. 2B** illustrates a zoomed in view demonstrating how yarns (10) are fed to the tack unit (62), after the air valve twist unit (64) the 6 yarns (10) go to the tack unit (62) together. **FIG. 2C** illustrates an air valve twist unit (64) in detail.

[0105] **FIG. 3A** illustrates a close-up of a yarn tension sensor (86) according to an embodiment of the invention. **FIG. 3B** illustrates a helicopter view of a yarn tension sensor (86) to show the device in perspective within the overall process. **FIG. 4A** illustrates a close-up of an automatic tensioner (84) according to an embodiment of the invention. **FIG. 4B** illustrates a helicopter view an automatic tensioner (84) to show the device in perspective within the overall process.

[0106] **FIG. 5A** illustrates level loop-pile carpets tufted with a yarn (1) according to an embodiment of the invention on the left-hand side, demonstrating the colour changes in the yarn (1) that become visible as colour changes in the carpet on the right-hand side. **FIG. 5B** and **FIG. 5C** (zoomed in) compare structure loop-pile carpets tufted with yarns according to the prior art on the left-hand side, to level loop-pile carpets tufted with a yarn (1) according to an embodiment of the invention on the right-hand side.

[0107] **FIG. 6** illustrates simplified representation of an intermingling process taking place in an air-entanglement and/or air-twisting unit (60), more specifically an intermingling nozzle (60) according to an embodiment of the invention. The intermingling nozzle (60 comprises a compressed air inlet (61). Textured yarn (15) may enter the intermingling nozzle (60) and may exit as intermingled yarn (16), comprising interlacing points (17).

[0108] **FIG. 7** illustrates an example to illustrate the invention. Each grey scale corresponds to a different

twist level, for M=6 yarns.

Claims

1. A method for producing a yarn (1) with variable properties along the length of the yarn (1), the method comprising the steps of:

   a. providing M yarns (10) through M yarn feeders (20), wherein M is at least 2; and,
   b. providing an apparatus (100) comprising an air-entanglement and/or air-twisting unit (60) and M individually controllable valves, configured for feeding the M yarns (10) into the air-entanglement and/or air-twisting unit (60) under a set pressure;

   wherein the method comprises N stages; wherein each stage n ranging from 1 to N has a time duration Δt_n; and wherein each stage n ranging from 1 to N comprises the steps of:

   i. feeding each of the M yarns into each of the M valves to obtain a bundle of M tensioned twisted yarns, preferably wherein each yarn m of the M yarns is twisted under a variable Valve Parameter Set VP (VP_1n, ..., VP_Mn) defined by each valve m of the M valves, depending on the yarn m and depending on the stage n; wherein each stage n may differ in at least one Valve Parameter from the previous stage n-1; and,
   ii. optionally, feeding the bundle of M tensioned twisted yarns to an air-tack unit to fix them as a bundle defined by the Valve Parameter Set VP1 (VP1_1n, ..., VP1_Mn) and/or feeding the bundle of M tensioned twisted yarns to an air-entanglement unit to over-entangle the bundle of twisted yarns defined by the Valve Parameter Set VP2 (VP2_1n, ..., VP2_Mn) of said stage n; wherein each stage n may differ in at least one Valve Parameter from the previous stage n-1.

   thereby obtaining a yarn (1) comprising multiple sections with variable properties along the length of the yarn (1).

2. The method according to claim 1, wherein at least 2 of the M yarns (10) differ in at least one property parameter, preferably in at least one of following property parameters: colour, thickness, material, number of filaments, shape of filaments; preferably wherein at least 2 of the M yarns (10) differ in colour.

3. The method according to any one of claims 1 or 2, wherein M is at least 3, preferably at least 4, for example at most 8, for example at most 6.

4. The method according to any one of claims 1 to 3, wherein N is at least 10, for example at least 50.

5. The method according to any one of claims 1 to 4, wherein each valve of the M valves is a twist jet (64).

6. The method according to any one of claims 1 to 5, wherein the Valve Parameter Set VP refers to the pressure for obtaining M twisted yarn and/or wherein the Valve Parameter Set VP1 refers to the pressure of an air-tack unit to obtain a tacked bundle of twisted yarn and/or wherein the Valve Parameter Set VP2 refers to the pressure of an air-entanglement unit to obtain an over-entangled bundle of twisted yarn.

7. The method according to claim 6, wherein the feeding pressure may be varied between 0 and 9.0 bar.

8. The method according to any one of claims 1 to 7, further comprising the step of:
   c. providing, preferably by a computer program product, an MxN input matrix of Valve Parameters VP (VP_11, ..., VP_MN) and/or of Valve Parameters VP1 (VP1_11, ..., VP_MN) and/or of Valve Parameters VP2 (VP2_11, ..., VP_MN) to the apparatus;
   and automatically operating the apparatus (100) based on the MxN input matrix.

9. The method according to any one of claims 1 to 8, wherein the air-entanglement and/or air-twisting unit (60) operates at a pressure in the range of at least 1 bar and at most 20 bar, more preferably at least 2 bar and at most 15 bar, and even more preferably at least 4 bar and at most 12 bar, most preferably at least 7 and at most 10 bar.

10. The method of any one of claims 1 to 9, wherein the time duration Δt_n for each stage 1 to N at least 0.05 and at most 20.0 s.

11. The method of any one of claims 1 to 10, wherein the M yarns (10) are Bulk Continuous Filament (BCF) and/ or Continuous Multifilament (CF) yarns.

12. The method of any one of claims 1 to 11, wherein the M yarns (10) have a linear density of at least 150 dtex and at most 3000 dtex, for example at least 300 dtex and at most 1400 dtex, preferably at least 400 dtex and at most 1000 dtex, preferably at least 500 dtex and at most 800 dtex, preferably at least 600 dtex and at most 700 dtex, for example about 650 dtex.

13. A computer program or a computer-readable storage medium comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method according to any one of claims 1 to 12.

14. A yarn (1) with variable properties along the length of the yarn (1), produced by the method according to any one of claims 1 to 12.

15. A method for producing a floor covering, such as a carpet, a rug, or an artificial turf, with a variable design on the surface of the floor covering; the method comprising the steps of:

- performing the method according to any one of claims 1 to 12 to provide a yarn (1) with variable properties along the length of the yarn (1); and,
- tufting a floor covering, such as carpet, rug, or artificial turf, with the provided yarn (1) with variable properties along the length of the yarn (1);

thereby producing a floor covering, such as a carpet, rug, or artificial turf, with a variable design on the surface.

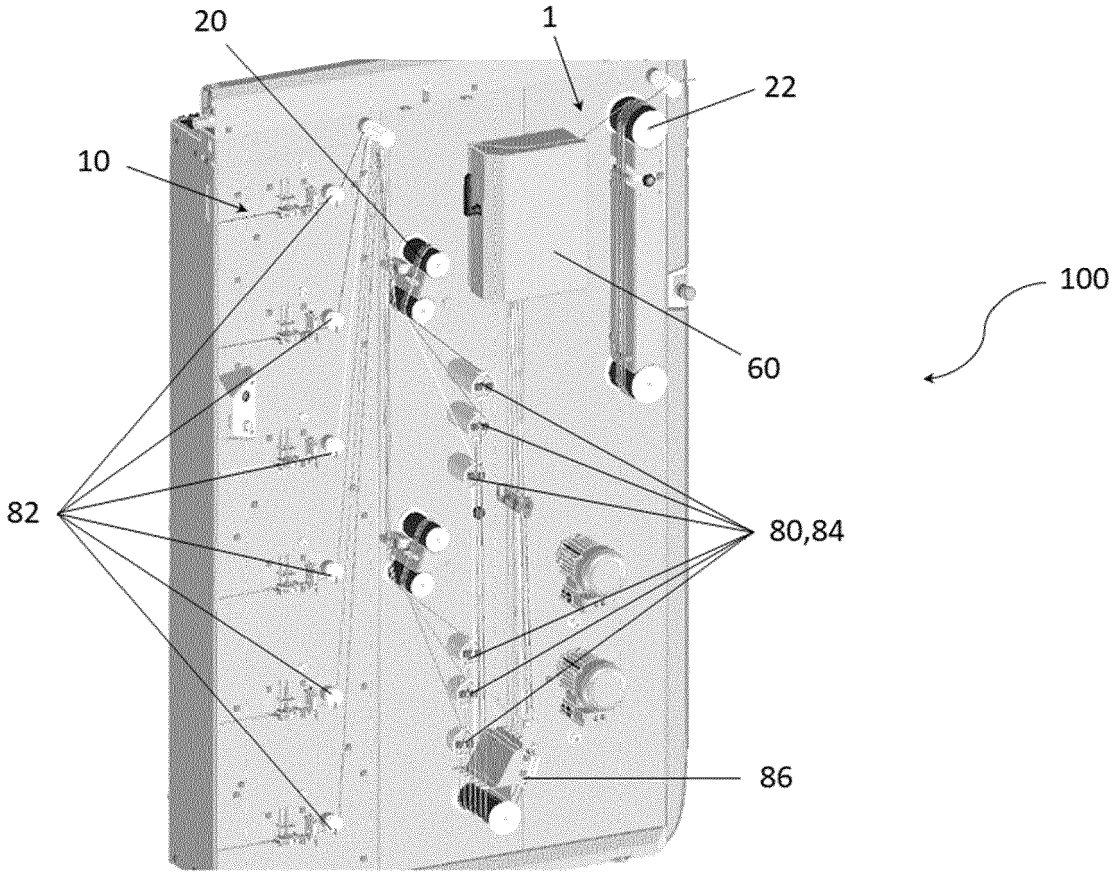


FIG. 1

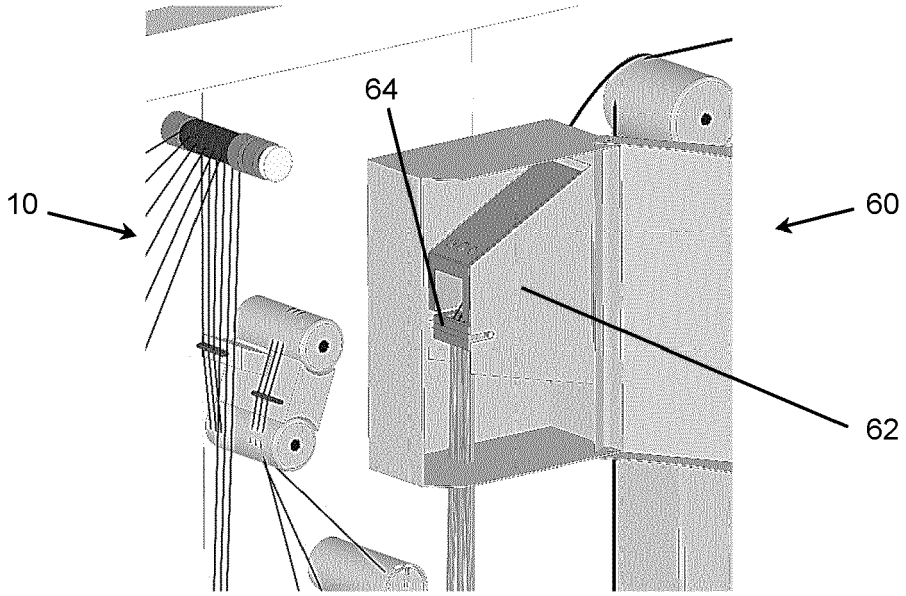


FIG. 2A

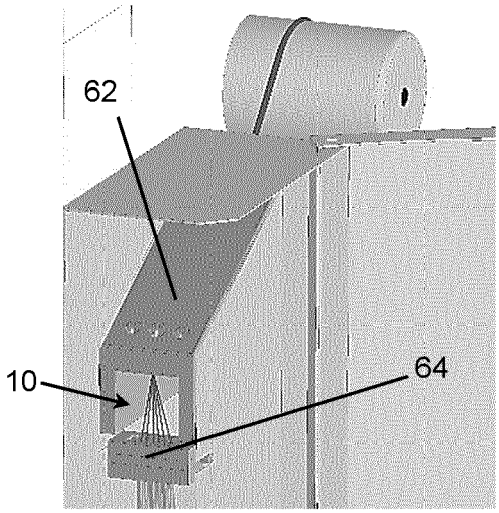


FIG. 2B

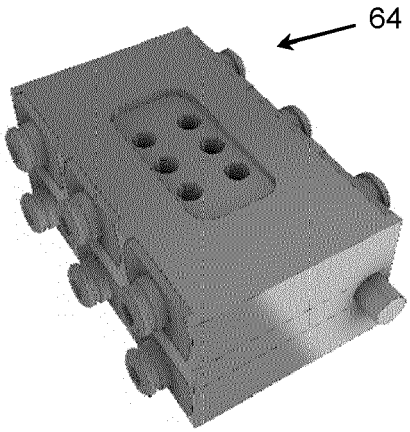
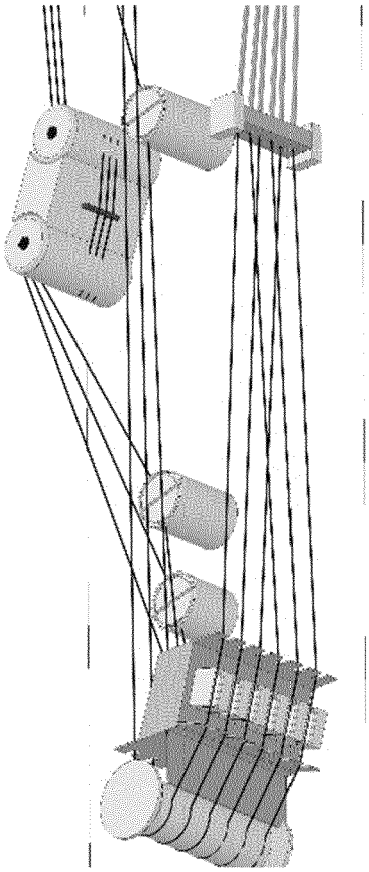


FIG. 2C

FIG. 3B



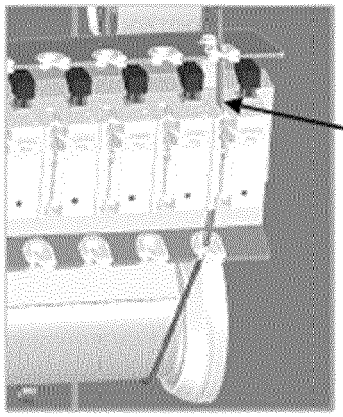
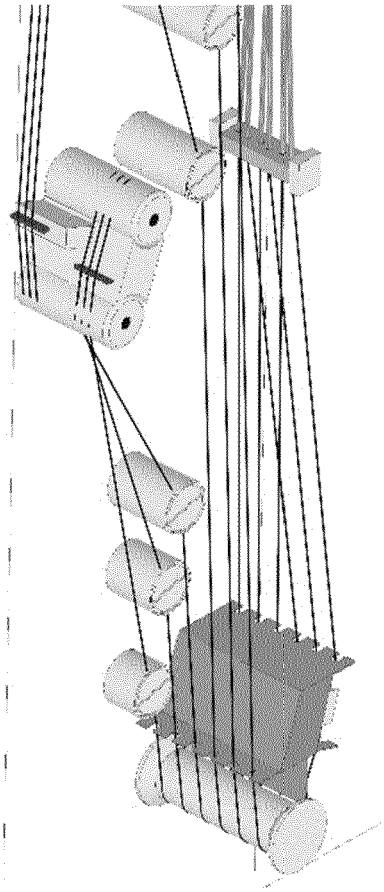


FIG. 3A

FIG. 4B



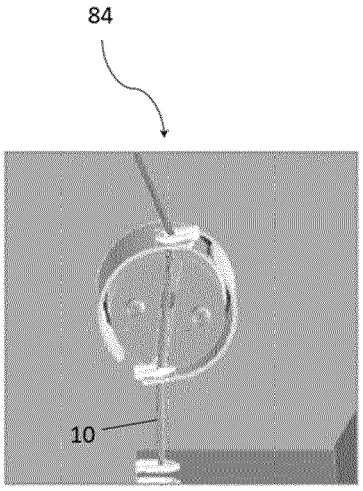


FIG. 4A

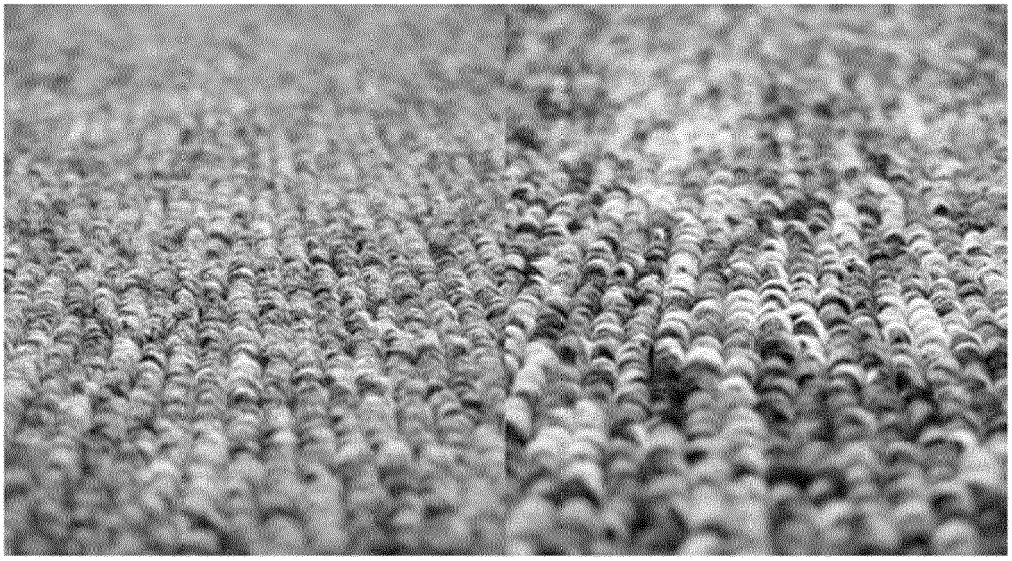


FIG. 5A

FIG. 5B

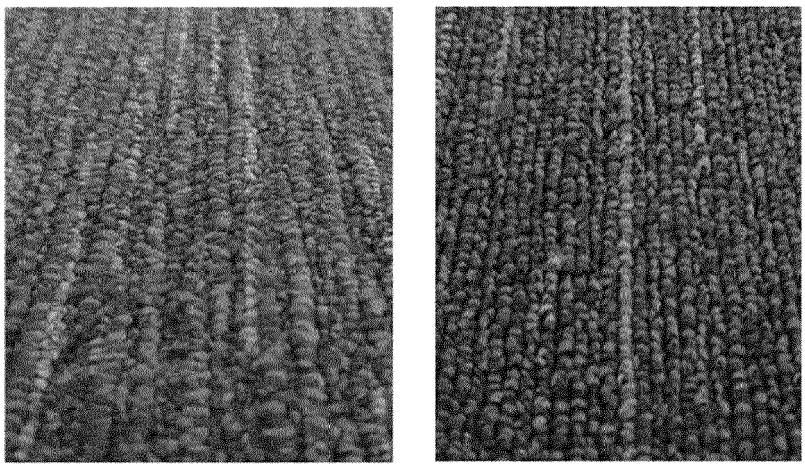


FIG. 5C

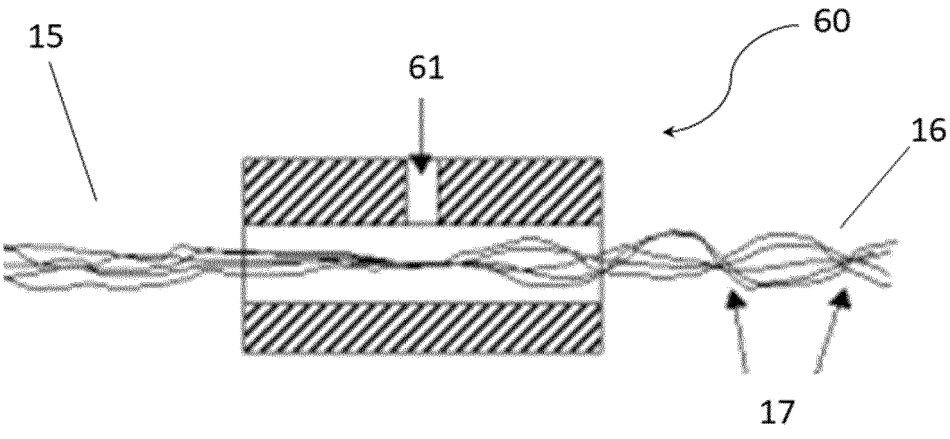


FIG. 6

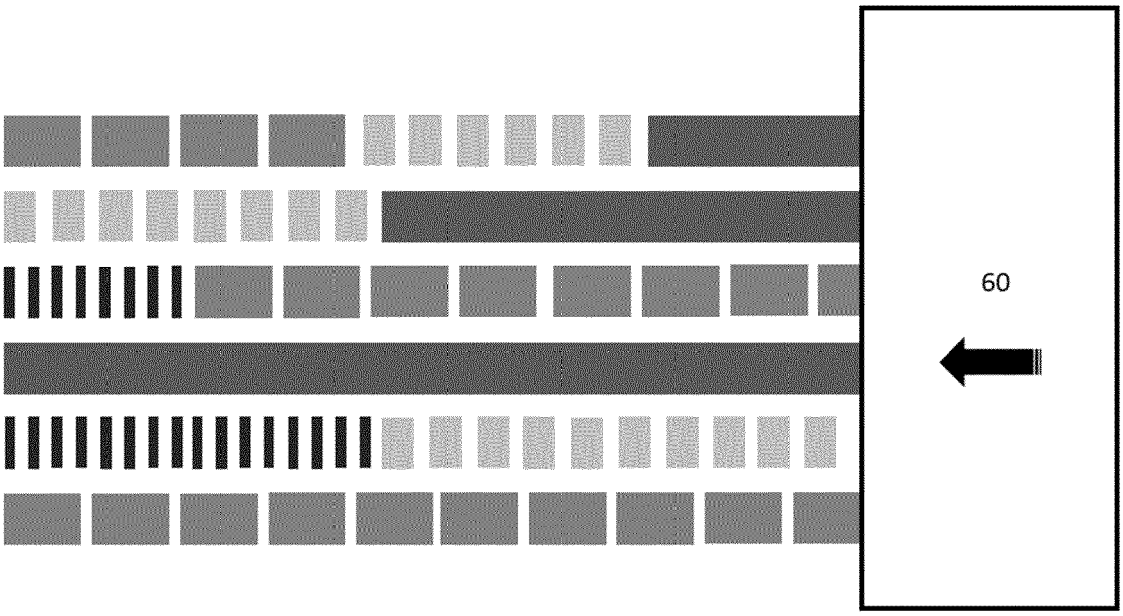


FIG. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 22 19 4546

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 5 056 200 A (SCHWARTZ NATHAN G [US] ET AL) 15 October 1991 (1991-10-15) * column 3, line 7 - column 4, line 28 *	1-15	INV. D02J1/08 D02G3/44 D02G1/16 D02G1/20 D02G3/34 D01D13/00
A	US 2021/388540 A1 (CASCIO ANTHONY [US] ET AL) 16 December 2021 (2021-12-16) * paragraphs [0025], [0029], [0039], [0042], [0065], [0071], [0073], [0088] - [0090] *	1-15	
A	US 2021/388531 A1 (CASCIO ANTHONY [US] ET AL) 16 December 2021 (2021-12-16) * paragraphs [0020], [0105]; figure 3b *	1-15	

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D02J
D02G
D01D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	3 March 2023	Van Beurden-Hopkins

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 22 19 4546

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03-03-2023

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