(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 335 956 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
13.03.2024 Bulletin 2024/11

(21) Application number: **22194551.2**

(22) Date of filing: **08.09.2022**

(51) International Patent Classification (IPC):
D02G 1/16 *(2006.01)* ***D02G 3/44*** *(2006.01)*
D02J 1/08 *(2006.01)* ***D02G 1/20*** *(2006.01)*
D02G 3/34 *(2006.01)* ***D01D 13/00*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
D02J 1/08; D01D 13/00; D02G 1/16; D02G 1/20; D02G 3/346; D02G 3/445

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

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(54) **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 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. The design may also be generated with

level loop using specific tufting technology (also known as Colorpoint), whereby the production speed is reduced at least by ¼. This also generates extra waste (10 to 15%) on the back stitch

[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 entangling from 2 to 6 yarn ends alternatively before entering the Air-Twisting process following a random or fixed pattern. 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 yarn entanglement apparatus for producing a yarn with variable properties along the length of the yarn. The yarn entanglement apparatus comprises one or more, preferably all of following features:

- M yarn feeders configured for feeding M yarns, wherein M is at least 2;
- M yarn cutting elements, configured for cutting each of the M yarns prior to feeding the M yarns to an air-entanglement and/or air-twisting unit; and,
- an air-entanglement and/or air-twisting unit.

[0015] In some preferred embodiments, the apparatus further comprises M yarn guiding elements, preferably positioned between the M cutting elements and the air-entanglement and/or air-twisting unit.

[0016] In some preferred embodiments, the apparatus further comprises a venturi type yarn injector, preferably positioned before the air-entanglement and/or air-twisting unit, for example M venturi type yarn injector position between the M yarn guiding elements and the air-entanglement and/or air-twisting unit.

[0017] In some preferred embodiments, the apparatus further comprises a yarn accumulator, preferably positioned after the air-entanglement and/or air-twisting unit.

[0018] In a second 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, wherein M is at least 2; and,
b. providing an apparatus according to the first aspect of the invention, or (preferred) embodiments thereof.

[0019] The method preferably comprises N stages, each with 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 at least one yarn m1 of the M yarns into the air-entanglement and/or air-twisting unit, while clamping at least one other yarn m2 of the M yarns, during a time duration Δt_n1;
ii. releasing the yarn m2, and feeding the yarn m2 simultaneous with the yarn m1 into the air-entanglement and/or air-twisting unit, during a time duration Δt_n2; wherein $\Delta t\_n = \Delta t\_n1 + \Delta t\_n2$; and,
iii. cutting at least one yarn selected from m1 or m2 before starting the next stage n+1; wherein at least

one of the yarns that is fed in step ii. Of stage n is not cut but maintained in step i. of stage n+1, such that the yarn continuous in the next section.

[0020] The method according to the second aspect of the invention thereby obtains a yarn comprising multiple sections with variable properties along the length of the yarn.

[0021] (Preferred) embodiments of the first aspect of the invention are also (preferred) embodiments of the second aspect of the invention, and vice versa.

[0022] 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.

[0023] In some preferred embodiments, M is at least 3, preferably at least 4, for example at most 8, for example 6.

[0024] 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.

[0025] 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.

[0026] In some preferred embodiments, the time duration Δt_n for each stage 1 to N is at least 1.0 s and at most 20.0 s.

[0027] In some preferred embodiments, the M yarns are Bulk Continuous Filament (BCF) and/ or Continuous Multifilament (CF) yarns.

[0028] 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.

[0029] In a third 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 second aspect of the invention, or (preferred) embodiments thereof.

[0030] (Preferred) embodiments of the first or second aspect of the invention are also (preferred) embodiments of the third aspect of the invention, and vice versa.

[0031] In a fourth aspect, the present invention provides a yarn with variable properties along the length of the yarn, produced with an apparatus according to the first aspect of the invention, or (preferred) embodiments thereof, or produced by the method according to the second aspect of the invention, or (preferred) embodiments thereof.

[0032] (Preferred) embodiments of the first or second aspect of the invention are also (preferred) embodiments of the fourth aspect of the invention, and vice versa.

[0033] In a fifth 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 second aspect of the invention, or (preferred) embodiments thereof, to provide a yarn with variable properties along the length of the yarn; or providing a yarn with variable properties along the length of the yarn according to the fourth aspect of the invention, or (preferred) embodiments thereof; 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.

[0034] The method according to the fifth aspect of the invention thereby produces a floor covering, such as a carpet, rug, or artificial turf, with a variable design on the surface.

[0035] In a sixth 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 fifth aspect of the invention, or (preferred) embodiments thereof.

[0036] (Preferred) embodiments of the first, second, or fourth aspect of the invention are also (preferred) embodiments of the fifth or sixth aspect of the invention, and vice versa.

[0037] 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.

[0038] 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

[0039]

FIG. 1 illustrates an embodiment of an apparatus (100) and method according to the invention. **FIG. 1A** illustrates the full apparatus (100) and method leading to the final yarn (1), while **FIG. 1B** illustrates a close-up of the entry of the yarns (10) to the air-entanglement and/or air-twisting unit (60).

FIG. 2 illustrates different types of yarn (1) that may be produced according to embodiments of the invention. **FIG. 2A** illustrates the sections that are present in yarn (1) of Type I. **FIG. 2B** illustrates the sections that are present in yarn (1) of Type II. **FIG. 2C** illustrates the sections that are present in yarn (1) of Type III.

FIG. 3A and **FIG. 3B** illustrate level loop-pile carpets tufted with a yarn (1) according to an embodiment of the invention. **FIG. 3C (left)** and **FIG. 3D (left)** illustrate structure loop-pile carpets not tufted with a yarn according to an embodiment of the invention. **FIG. 3C (right)** and **FIG. 3D (tight)** illustrate level loop-pile carpets tufted with a yarn (1) according to an embodiment of the invention.

FIG. 4 illustrates a venturi type injector (50) suitable for an embodiment of the invention.

FIG. 5 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.

[0040] 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
(12)	bobbin
(15)	textured yarn
(16)	intermingled yarn
(17)	interlacing points
(20)	yarn feeders, from 2 .. M
(22)	feeding rolls
(24)	motor
(30)	cutting elements, from 2 .. M
(40)	guiding elements, from 2 .. M
(50)	venturi type injector, from 2 .. M
(51)	vortex assembly
(52)	fibre inlet
(53)	fibre exit
(54)	main hole
(55)	sub hole at an injector angle
(56)	outer assembly
(57)	compressed air inlet
(58)	air reservoir
(60)	air-entanglement and/or air-twisting unit
(61)	compressed air inlet
(70)	yarn accumulator

DETAILED DESCRIPTION OF THE INVENTION

[0041] When describing the invention, the terms used are to be construed in accordance with the following definitions, unless a context dictates otherwise.

[0042] 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.

[0043] 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".

[0044] 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.

[0045] 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.

[0046] 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.

[0047] The terms described above, and others used in the specification are well understood to those skilled in the art.

[0048] 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.

[0049] 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.

[0050] 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.

[0051] In a first aspect, the present invention provides a yarn entanglement apparatus for producing a yarn with variable properties along the length of the yarn. The yarn entanglement apparatus comprises one or more, preferably all of following features:

- M yarn feeders, preferably positive yarn feeders, configured for feeding M yarns, wherein M is at least 2;
- optionally, M yarn guiding elements, configured for guiding M yarns towards the air-entanglement and/or ait-twisting unit;
- M yarn cutting elements, configured for cutting each of the M yarns prior to feeding the M yarns to an air-entanglement and/or air-twisting unit; and,
- an air-entanglement and/or air-twisting unit.

[0052] The apparatus preferably comprises M yarn feeders, preferably positive yarn feeders, configured for feeding M yarns, wherein M is at least 2. 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 during the transition phase instead of being a merely passive feeder and provides controlled feeding length 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. The yarn feeders may also be used as or may comprise clamping elements.

[0053] The apparatus preferably comprises M yarn cutting elements, configured for cutting each of the M yarns prior to feeding the M yarns to an air-entanglement and/or air-twisting unit. Each yarn cutting element comprises a cutting element, configured to cut the yarn. The cutting element may be positioned after the guiding element.

[0054] The yarn cutting open motion preferably allows the free yarn to be properly drawn by Venturi. The yarn feeder start/stop may be delayed from the yarn cutting elements, to accumulate some free yarn within the yarn guide element ready to be sucked properly by Venturi.

[0055] 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 bursts (e.g., only operational when there are 2 or more yarns present, but not operational if there is only 1 yarn present). 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. The air-entanglement and/or air-twisting unit allows for 2 or more yarns to be entangled and form a new yarn.

[0056] In some preferred embodiments, the apparatus further comprises M yarn guiding elements, preferably positioned between the M feeding elements and the air-entanglement and/or air-twisting unit; preferably positioned between the feeding elements and the cutting elements. The yarn guiding elements may be tubes, for example metal or plastic tubes. The yarn guiding elements keep the yarn stable from any environment conditions (air flow, etc..) and may be used to conserve space. The yarn guiding elements may have a length from 5 cm to 100 cm, preferably from 20 cm to 50 cm. The yarn guiding elements may have an inner diameter from 2.0 mm to 8.0 mm, preferably from 3.5 mm to 4.0 mm. The yarn guiding elements ensure that the correct yarns are brought closely to the entrance of Venturi and/or the air-entanglement and/or air-twisting unit, are properly fed into the air-entanglement and/or air-twisting unit, and do not get entangled prior to entering the air-entanglement and/or air-twisting unit. They also allow the other elements of the apparatus, such as the cutting element and/or the yarn feeders, to be properly spaced apart, despite the relatively small entry to the air-entanglement and/or air-twisting unit. This allows for proper guiding and/or accumulation of yarn.

[0057] In some preferred embodiments, the apparatus further comprises a venturi type yarn injector, preferably positioned before the air-entanglement and/or air-twisting unit, for example M venturi type yarn injector position between the M yarn guiding elements and the air-entanglement and/or air-twisting unit. Such an injector ensures proper and quick feeding of the yarns into an air-entanglement and/or air-twisting unit.

[0058] In some preferred embodiments, the apparatus further comprises a yarn accumulator, preferably positioned after the air-entanglement and/or air-twisting unit.

[0059] 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.

[0060] In some embodiments, the apparatus further comprises a yarn printer. Preferably the yarn printer is located after the air-entanglement and/or air-twisting unit. This yarn printer may provide additional colour to the yarn exiting the air-entanglement and/or air-twisting unit and may be preferred when light-coloured yarns are used.

[0061] In a second 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, wherein M is at least 2; and,
b. providing an apparatus according to the first aspect of the invention, or (preferred) embodiments thereof.

[0062] The method preferably comprises N stages, each with 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 at least one yarn m1 of the M yarns into the air-entanglement and/or air-twisting unit, while clamping at least one other yarn m2 of the M yarns, during a time duration Δt_n1;
ii. releasing the yarn m2, and feeding the yarn m2 simultaneous with the yarn m1 into the air-entanglement and/or air-twisting unit, during a time duration Δt_n2; wherein $\Delta t\_n = \Delta t\_n1 + \Delta t\_n2$; and,
iii. cutting at least one yarn selected from m1 or m2 before starting the next stage n+1; wherein at least one of the yarns that is fed in step ii. Of stage n is not cut but maintained in step i. of stage n+1, such that the yarn continuous in the next section.

[0063] The method according to the second aspect of the invention thereby obtains a yarn comprising multiple sections with variable properties along the length of the yarn.

[0064] (Preferred) embodiments of the first aspect of the invention are also (preferred) embodiments of the second aspect of the invention, and vice versa.

[0065] 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.

[0066] 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.

[0067] The method preferably comprises N stages, each with a time duration Δt_n. Each of these N stages will comprise 2 sub-stages, each with a time duration Δt_n1 and Δt_n2, wherein $\Delta t\_n = \Delta t\_n1 + \Delta t\_n2$. During each stage, 2 different types of yarn are produced, wherein each sub-stage produces a different section.

[0068] Each stage n ranging from 1 to N preferably comprises the step i. of feeding at least one yarn m1 of the M yarns into the air-entanglement and/or air-twisting unit, while clamping at least one other yarn m2 of the M yarns, during a time duration Δt_n1. This sub-stage allows for a section to be produced wherein the yarn comprises yarn m1 but does not comprise yarn m2. In some embodiments, step i. of some or all N stages comprises feeding exactly one yarn into the air-entanglement and/or air-twisting unit. In some embodiments, step i. of some or all N stages comprises feeding more than one yarn into the air-entanglement and/or air-twisting unit.

[0069] Each stage n ranging from 1 to N preferably comprises the step ii. of releasing the yarn m2 and feeding the yarn m2 simultaneous with the yarn m1 into the air-entanglement and/or air-twisting unit, during a time duration Δt_n2. This sub-stage allows for a section to be produced wherein the yarn comprises both yarn m1 as well as yarn m2. This section may also be called a change-over section. In some embodiments, step ii. of some or all N stages comprises feeding exactly two yarns into the air-entanglement and/or air-twisting unit. In some embodiments, step ii. of some or all N stages comprises feeding more than two yarns into the air-entanglement and/or air-twisting unit.

[0070] In some embodiments, a sub-stage comprising only 1 colour of yarn is shorter than a sub-stage comprising multiple differently coloured yarns. This shorter section may be called a change-over section. In some embodiments, a sub-stage comprising multiple differently coloured yarns may be shorter than a sub-stage comprising only 1 colour of yarn. This shorter section may be called a change-over section.

[0071] Each stage n ranging from 1 to N preferably comprises the step of cutting at least one yarn selected from m1 or m2 before starting the next stage n+1. This action allows for a new section to be produced, without yarn m1 or m2. At least one of the yarns that is fed in step ii. is not cut but maintained in step i., such that the yarn continuous in the next section.

[0072] The method may be continuous or discrete, preferably the method is continuous.

[0073] 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.

[0074] 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.

[0075] 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.

[0076] The yarns may comprise polyamide (such as nylon), polypropylene, polyethylene, polyester, wool, and/or any other raw material.

[0077] In some preferred embodiments, M is at least 3, preferably at least 4, for example at most 8, for example 6. This number of yarns was found to be ideal

[0078] 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.

[0079] In some embodiments, there is repetition between the sections. In some embodiments, there is no repetition between the sections.

[0080] In some embodiments, each stage n ranging from 1 to N comprises the step of applying an Air Entanglement Parameter AE_n in the air-entanglement and/or air-twisting unit depending on the stage n or depending on the sub-stage; wherein at least one stage n differs in at least in one Air Entanglement Parameter AE_n from the Air Entanglement Parameter AE_n-1 from the previous stage n-1. In some embodiments, the Air Entanglement Parameter is defined as the pressure of the air-entanglement and/or air-twisting unit.

[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 1.0 s and at most 20.0 s, for example at least 2.0 s and at most 15.0 s, for example at least 5.0 s and at most 10.0 s. In some embodiments, the time duration Δt_n1 and/or Δt_n2 for each sub-stage is at least 0.5 s and at most 18.0 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 after exiting 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 M is lower, such as 2 or 3, the dtex of each of the yarns separately may be in the higher range. Conversely, if M is higher, such as 5 or 6, the dtex of each of the yarns separately 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 a third 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 second 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 second aspect of the invention, or (preferred) embodiments thereof.

[0088] (Preferred) embodiments of the first or second aspect of the invention are also (preferred) embodiments of the third aspect of the invention, and vice versa.

[0089] In some embodiments, the apparatus as described herein comprises a computer. In some embodiments, the method as described herein is a computer-implemented method.

[0090] In a fourth aspect, the present invention provides a yarn with variable properties along the length of the yarn, produced with an apparatus according to the first aspect of the invention, or (preferred) embodiments thereof, or produced by the method according to the second aspect of the invention, or (preferred) embodiments thereof.

[0091] (Preferred) embodiments of the first or second aspect of the invention are also (preferred) embodiments of the fourth aspect of the invention, and vice versa.

[0092] 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.

[0093] In some embodiments, the yarn is a Type I yarn. Type I yarn may be defined as yarn comprising A - AB - B sections (and variations thereof), wherein the yarn changes from yarn A to yarn B with a change-over AB. The change-over section AB is preferably smaller than sections A and B, preferably at most 0.5 x the average size of sections A and B, preferably at most 0.2 x the average size of sections A and B, for example at most 0.1 x the average size of sections A and B.

[0094] In some embodiments, the yarn is a Type II yarn. Type II yarn may be defined as yarn comprising A - AB - A sections (and variations thereof), wherein the yarn changes comprise a constant A yarn, with sections whereby one or more additional B yarns are superimposed. The constant yarn A may also be referred to as carrier yarn. The AB section may be smaller than the A sections, preferably at most 0.5 x the average size of average size of the A sections, preferably at most 0.2 x, for example at most 0.1 x. Alternatively, the AB section may be larger than the A sections, preferably at least 2 x the average size of the A sections, preferably at least 5 x the average size, for example at least 10 x the average size.

[0095] In some embodiments, the yarn is a Type III yarn. Type III yarn may be defined as yarn comprising A - AB - B sections (and variations thereof), wherein the yarn changes from yarn A to yarn B via AB. The section AB is preferably larger than sections A and B, preferably at least 2 x the average size of sections A and B, preferably at least 5 x the average size of sections A and B, for example at least 10 x the average size of sections A and B.

[0096] In some embodiments, the yarn is a combination of Type I and Type II yarn. In some embodiments, the yarn is a combination of Type I and Type III yarn. In some embodiments, the yarn is a combination of Type II and Type III yarn. In some embodiments, the yarn is a combination of Type I, Type II, and Type III yarn.

[0097] In a fifth 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 the carpet, rug, or artificial turf. The method preferably comprises one or more, preferably all, of the steps of:

- performing the method according to the second aspect of the invention, or (preferred) embodiments thereof, to provide a yarn with variable properties along the length of the yarn; or providing a yarn with variable properties along the length of the yarn according to the fourth aspect of the invention, or (preferred) embodiments thereof; 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.

[0098] The method according to the fifth aspect of the invention thereby produces a floor covering, such as a carpet, rug, or artificial turf, with a variable design on the surface.

[0099] In a sixth 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 carpet, rug, or artificial turf, produced by the method according to the fifth aspect of the invention, or (preferred) embodiments thereof.

[0100] (Preferred) embodiments of the first, second, or fourth aspect of the invention are also (preferred) embodiments of the fifth or sixth aspect of the invention, and vice versa.

[0101] 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.

[0102] 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.

[0103] 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.

[0104] 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

[0105] 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.

[0106] FIG. 1 illustrates an embodiment of an apparatus (100) and method according to the invention.

[0107] FIG. 1A illustrates the full apparatus (100) and method leading to the final yarn (1). Six bobbins (12) comprising six yarns (10), labelled A to F, are unwound and fed to the apparatus (100) (only 4 bobbins (12) and yarns (10) A-D are explicitly shown). 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) A-F is connected to a cutting element (30), configured for cutting each yarn (10). The apparatus (100) also comprises a yarn guiding element (40) for each yarn (10) A-F, such that yarns (10) that are not cut and clamped, are fed into their respective yarn guiding elements (40). The yarn guiding elements (40) guide the yarns (10) into 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 stored in a yarn accumulator (70).

[0108] **FIG. 1B** illustrates a close-up of the entry of the yarns (10) to the air-entanglement and/or air-twisting unit (60) according to an embodiment of the invention. Each of five yarns (10), herein labelled as A-E, may be fed to the air-entanglement and/or air-twisting unit (60), but details are only shown for yarn C. Yarn C is connected to a positive yarn feeder (20), comprising two rolls (22) and a small electric motor (24), with a feeding speed of 500 m/min. Subsequently, yarn C is connected to a cutting element (30), configured for cutting yarn C. Subsequently, yarn C is fed to yarn guiding element (40), which guides yarn C into the air-entanglement and/or air-twisting unit (60, via a venturi type yarn injector (50).

[0109] **FIG. 2** illustrates different types of yarn (1) that may be produced according to embodiments of the invention.

[0110] **FIG. 2A** illustrates the sections that are present in yarn (1) of Type I. This type of yarn comprises A - AB - B sections (and variations thereof), wherein the yarn changes from yarn A to yarn B with a change-over AB. The change-over sections are smaller than the sections comprising a single yarn. In this example, the yarn comprises the following sections: A / AD (change-over) / D / DB (change-over) / B / BA (change-over) / A / AC (change-over) / C.

[0111] If each of the yarns A, B, C, and D comprise a different colour (or darkness), this will result in a yarn comprising sections with different colours. For example, if A is blue, B is red, D is black, and C is white, this sequence would result in following colour sections:
blue / dark blue (small) / black / dark red (small) / red / purple (small) / blue / light blue (small).

[0112] If the change-over sections are much smaller than sections comprising a single yarn, such that they become negligible when tufting a floor covering such as a carpet, this would visually result in a yarn with following colour sections: blue / black / red / blue.

[0113] **FIG. 2B** illustrates the sections that are present in yarn (1) of Type II This type of yarn comprises C - CD - C sections (and variations thereof), wherein the yarn changes comprise a constant C yarn, with sections whereby one or more additional D yarns are superimposed.

[0114] In this example, the CD sections are larger than the C sections. In this example, the change-over occurs at the sections with only a single C yarn, and these sections are smaller than the sections comprising two different yarns. In this example, the yarn comprises the following sections:
C (change-over) / CD / C (change-over) / CB / C (change-over) / CA / C (change-over).

[0115] If each of the yarns A, B, C, and D comprise a different colour (or darkness), this will result in a yarn comprising sections with different colours. For example, if A is blue, B is red, D is black, and C is white, this sequence would result in following colour sections:
white (small) / grey (light black) / white (small) / pink (light red) / white (small) / light blue / white (small).

[0116] If the change-over sections of the carrier yarn C are much smaller than the sections comprising multiple yarns, such that they become negligible when tufting a floor covering such as a carpet, this would visually result in a yarn with following colour sections:
grey / pink / light blue.

[0117] **FIG. 2C** illustrates the sections that are present in yarn (1) of Type III. This type of yarn comprises A - AB - B sections (and variations thereof), wherein the yarn changes from yarn A to yarn B with a change-over AB. In this example, the change-over occurs at the sections with only a single yarn, and these sections are smaller than the sections comprising two different yarns. In this example, the yarn comprises the following sections:
A (change-over) / AD / D (change-over) / DB / B (change-over) / BA / A (change-over) / AC / C (change-over).

[0118] If each of the yarns A, B, C, and D comprise a different colour (or darkness), this will result in a yarn comprising sections with different colours. For example, if A is blue, B is red, D is black, and C is white, this sequence would result in following colour sections:
blue (small) / dark blue / black (small) / dark red / red (small) / purple / blue (small) / light blue.

[0119] If the change-over sections comprising a single yarn are much smaller than the sections comprising multiple yarns, such that they become negligible when tufting a floor covering such as a carpet, this would visually result in a yarn with following colour sections:
dark blue / dark red / purple / light blue.

[0120] **FIG. 3A** 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.

[0121] **FIG. 3B** and **FIG. 3C** (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.

[0122] **FIG. 4** illustrates a venturi type injector (50) suitable for an embodiment of the invention. venturi type injector (50) comprises a vortex assembly (51) within an outer assembly (56). The vortex assembly (51) comprises a fibre inlet (52) and a fibre exit (53), connected through a main hole (54). The vortex assembly (51) also comprises one or more sub holes (55), positioned at an injector angle compared to the main hole (54). The outer assembly (56) comprises a compressed air inlet (57), feeding an air reservoir (58). The air reservoir (58) is connected to the main hole (54) through the sub hole(s) (55).

[0123] **FIG. 5** 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).

Claims

1. A yarn entanglement apparatus (100) for producing a yarn (1) with variable properties along the length of the yarn (1), the yarn entanglement apparatus (100) comprising:

- M yarn feeders (20) configured for feeding M yarns (10), wherein M is at least 2;
- M yarn cutting elements (30), configured for cutting each of the M yarns (10) prior to feeding the M yarns (10) to an air-entanglement and/or air-twisting unit (60); and,
- an air-entanglement and/or air-twisting unit (60).

2. The apparatus (100) according to claim 1, further comprising M yarn guiding elements (40), configured for guiding M yarns towards the air-entanglement and/or ait-twisting unit; preferably positioned between the cutting elements (30) and the yarn feeders (20).

3. The apparatus (100) according to any one of claims 1 or 2, further comprising a venturi type yarn injector (50), positioned before the air-entanglement and/or air-twisting unit (60).

4. The apparatus (100) according to any one of claims 1 to 3, further comprising a yarn accumulator (70), positioned after the air-entanglement and/or air-twisting unit (60).

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

a. providing M yarns (10), wherein M is at least 2; and,
b. providing an apparatus (100) according to any one of claims 1 to 4;
wherein the method comprises N stages each with a time duration Δt_n; wherein each stage n ranging from 1 to N comprises the steps of:

i. feeding at least one yarn m1 of the M yarns (10) into the air-entanglement and/or air-twisting unit (60), while clamping at least one other yarn m2 of the M yarns (10), during a time duration Δt_n1;
ii. releasing the yarn m2, and feeding the yarn m2 simultaneous with the yarn m1 into the air-entanglement and/or air-twisting unit, during a time duration Δt_n2; wherein Δt_n = Δt_n1 + Δt_n2; and,
iii. cutting at least one yarn selected from m1 or m2 before starting the next stage n+1; wherein at least one of the yarns that is fed in step ii. Of stage n is not cut but maintained in step i. of stage n+1, such that the yarn continuous in the next section;

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

6. The method according to claim 5, 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.

7. The method according to any one of claims 5 or 6, wherein M is at least 3, preferably at least 4, for example at most 8, for example 6.

8. The method according to any one of claims 5 to 7, wherein N is at least 10, for example at least 50.

9. The method according to any one of claims 5 to 8, wherein the air-entanglement and/or air-twisting unit (70) 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 is at least 1.0 s, optionally 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 5 to 12.

14. A yarn (1) with variable properties along the length of the yarn (1), produced with an apparatus (100) according to any one of claims 1 to 4, or produced by the method according to any one of claims 5 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 5 to 12 to provide a yarn (1) with variable properties along the length of the yarn (1); or providing a yarn (1) with variable properties along the length of the yarn according to claim 14; 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.

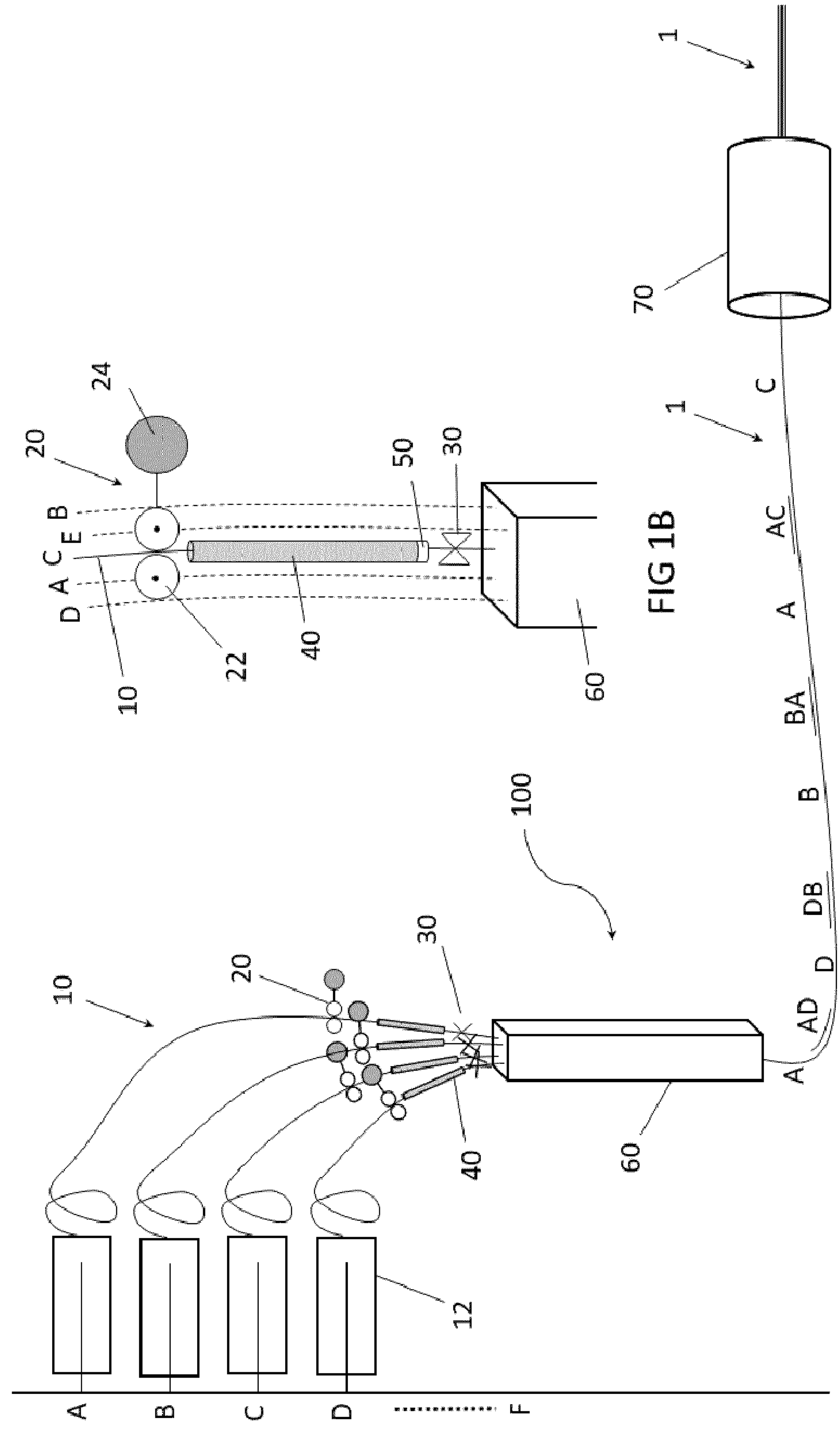
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FIG 1B

FIG 1A

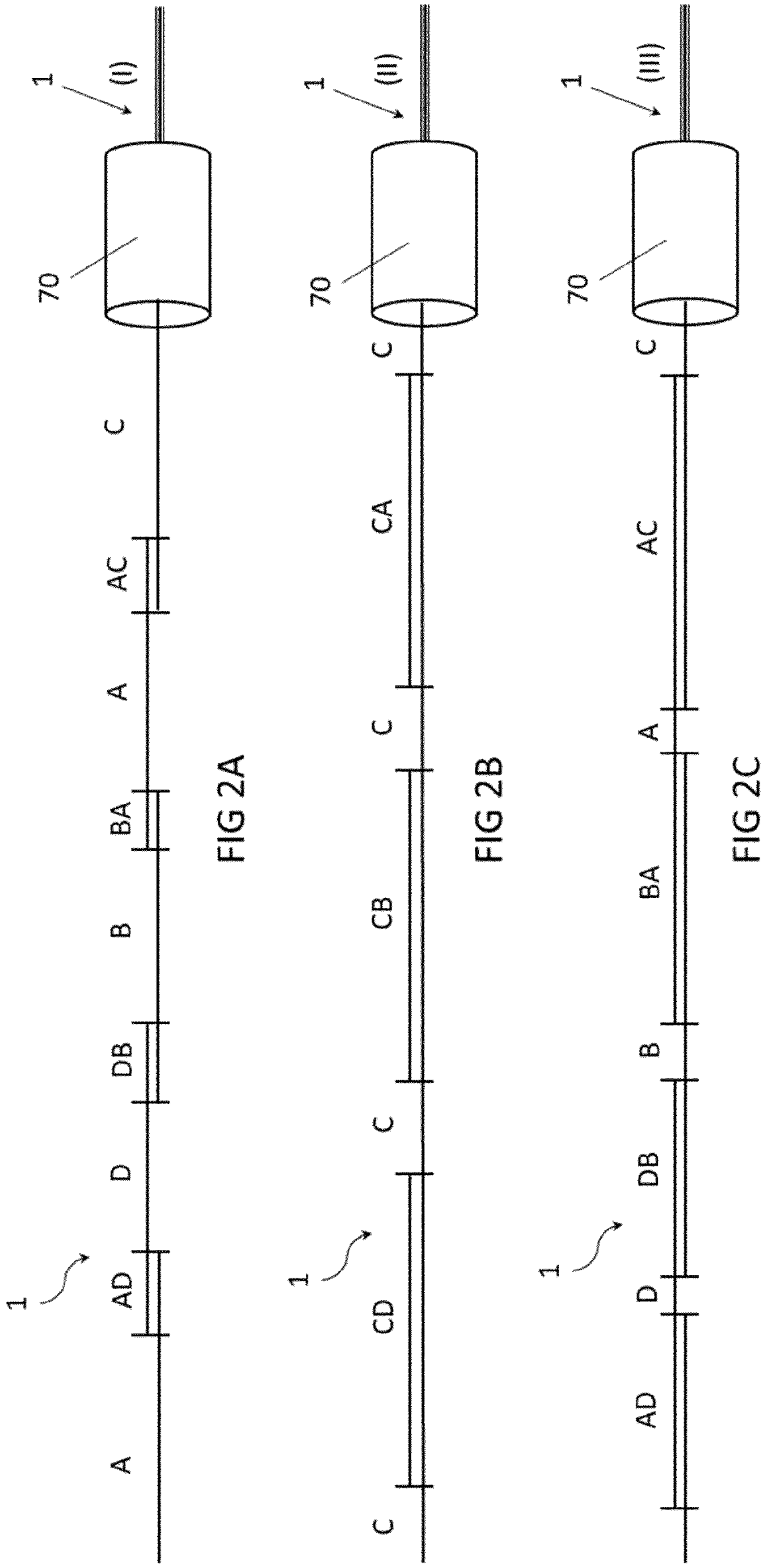

FIG 2A

FIG 2B

FIG 2C

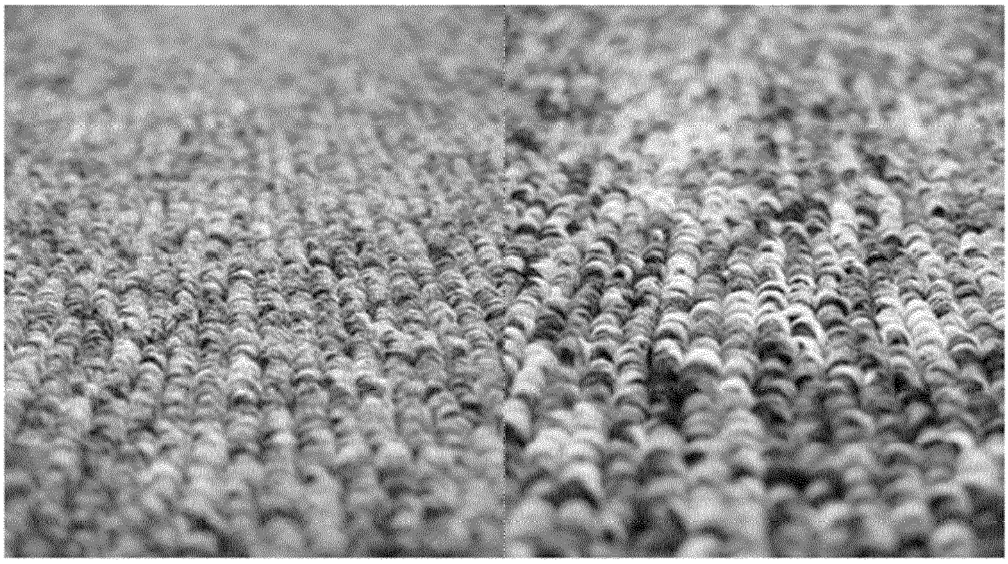

FIG 3A

FIG 3B

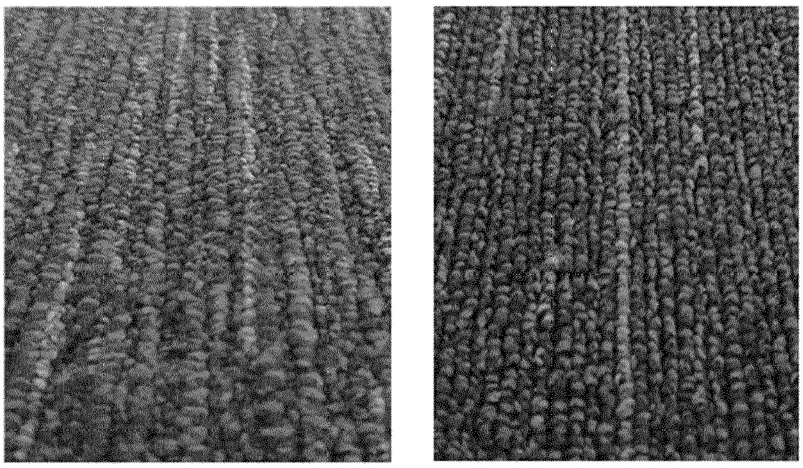

FIG 3C

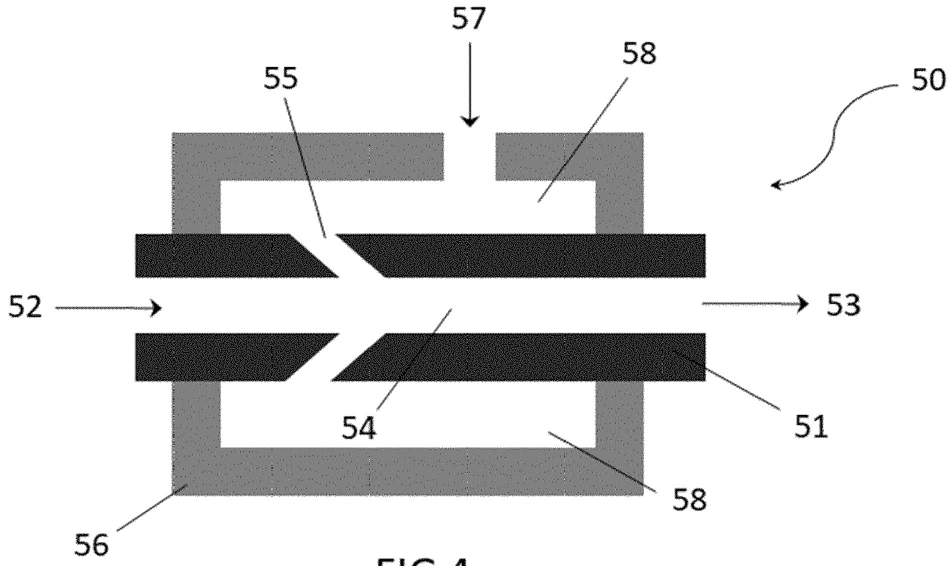

FIG 4

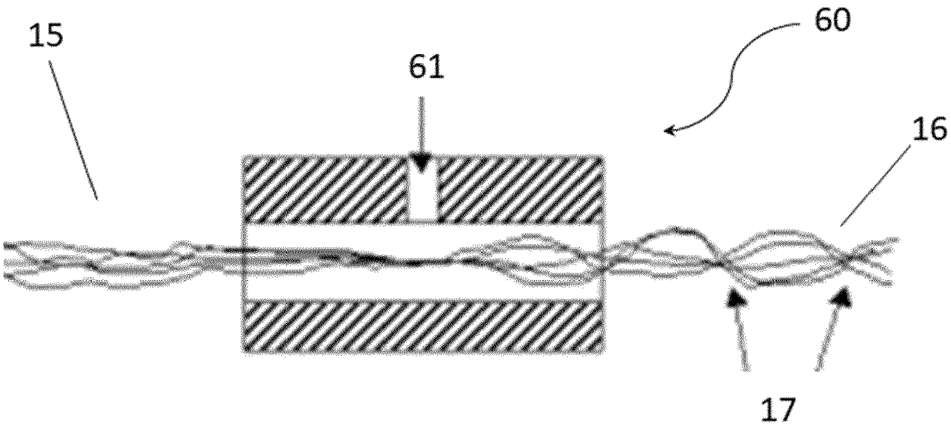

FIG 5

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EUROPEAN SEARCH REPORT

Application Number
EP 22 19 4551

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 2021/388540 A1 (CASCIO ANTHONY [US] ET AL) 16 December 2021 (2021-12-16) * paragraphs [0025], [0029], [0039], [0042], [0071], [0073], [0088] - [0090]; figure 4 * -----	1-15	INV. D02G1/16 D02G3/44 D02J1/08 D02G1/20 D02G3/34 D01D13/00
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			D02G D02J D01D

The present search report has been drawn up for all claims

1

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

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