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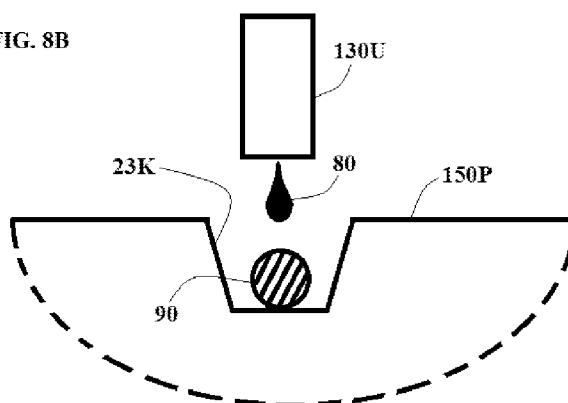
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(54) Title: APPLYING AN AGENT TO A FLEXIBLE FILAMENT

FIG. 8B



(57) Abstract: A process can include contacting a filament, such as an elongate substrate, with a trough. A process can also include transferring an agent, such as an additive to the elongate substrate. The transferring can include applying the additive directly to the elongate substrate in the trough, applying the additive directly to the trough and transferring the additive from the trough to the elongate substrate, or a combination thereof. The additive can be a colorant.

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APPLYING AN AGENT TO A FLEXIBLE FILAMENT

RELATED APPLICATION

[0001] This application claims priority to Provisional Application No, 62/771,884 filed on November 27, 2018 and Provisional Application No. 62/884,183, filed August 08, 2019, which are incorporated herein by reference in their entirety.

FIELD

[0002] Disclosed are methods, devices, and systems for applying an agent, such as a colorant, to an elongate flexible substrate, such as a filament, a yarn, a thread or a wire.

BACKGROUND

[0003] Technologies for applying additives to fibers have a wide variety of uses. For example, additives such as colorant can be applied to carpet yarn to manufacture colored carpet. The conventional technology for coloring carpet (e.g., surface-printing) can require large and expensive equipment and can be time-consuming. Colors cannot be changed without substantial equipment downtime. Furthermore, coloring carpet after manufacturing also results in uneven distribution of colorant since only the upper portion of the fiber is accessible from the top of the finished carpet.

[0004] US20140349034 refers to a device and system for dynamically applying liquid to a single thread for a thread consuming device as said thread moves relative to the device along a path of movement.

[0005] WO2017203524A1 refers to treating threads or parts thereof using a machine having one or more cartridges each configured for containing thread treatment-material therein; one or more injectors, each injector being configured for

applying treatment-material from its respective cartridge over a passing portion of the thread; drive means for operating the one or more injectors; and a communication and control unit for receiving treatment plan data indicative of at least one machine readable treatment related parameter associated with at least one treatment effect for each thread portion to be treated for controlling the treatment effect of each passing thread portion, according to the received treatment plan data.

[0006] It appears that neither US US20140349034 and WO2017203524A1 are suitable for coloring multiple yarns at the same time. Traditional (analog) methods of yarn coloration commonly used in carpet industry, such as space dyeing, lack color uniformity and are not suitable for producing uniform solid colors. Color change on these machines also requires substantial equipment downtime.

[0007] Solution dyed yarns is another approach to manufacturing colored carpet. Changing designs and changing colors using a solution dyed yarns can lead to yarn waste during yarn processing and substantial equipment downtime in a carpet manufacturing process.

SUMMARY

[0008] Difficulties in selectively applying color to individual yarn or yarn bundles is costly and inefficient using existing technologies. The instant disclosure provides technology for applying an agent, such as a colorant, to individual yarns for use in manufacturing textile goods, such as bulked yarns for carpet. An example of the present subject matter allows for applying colorant in a manner that provides control of color transitions to provide crisp or gradual color transitions.

[0009] Various embodiments provide a process for applying an additive to an elongate substrate. A process includes contacting the elongate substrate with the trough. A process also includes transferring the additive to the elongate substrate. Transferring includes applying the additive directly to the elongate substrate in the trough, applying the additive directly to the trough and transferring the additive from the trough to the elongate substrate, or a combination thereof. In some embodiments, a process includes first applying the additive to the trough, and thereafter transferring the additive from the trough to the elongate substrate. The

gap distance between the point of applying colorant to the trough and the point of transfer can be small in order to keep equipment size small and cost low.

[0010] Various embodiments provide a device for applying additive to an elongate substrate. An example device includes a grooved surface including at least one groove. An example device also includes an additive dispenser to selectively apply additive directly onto the elongate substrate or onto a groove of the grooved surface. In this document, the terms groove and trough are used interchangeably.

[0011] Various embodiments of the present subject matter provide certain advantages over other methods and devices for applying additives to elongate substrates. For example, in various embodiments, the present subject matter can provide selective application of additives, such as colorants, to individual elongate substrates. In various embodiments, the method and device of the present subject matter provides on-demand access to a variety of additives such as multiple colors and multiple chemical treatments such as water-resistant coatings. In various embodiments, the method and device of the present subject matter can apply additives evenly to the entire elongate substrate, such as to the entire tuft of a carpet (e.g., length, depth, width), instead of only to the surface as occurs with surface-printed carpet. In various embodiments, the on-demand access to various additives of the present subject matter can avoid the equipment reconfiguration needed when applying additives directly to finished carpet.

[0012] Printing carpet is substantially more complex than printing on paper or printing on a solid surface. In some examples, the present subject matter entails applying colorant prior to processing using a tufting machine.

[0013] In various embodiments, the present subject matter can provide a high degree of control over the transition between additives such as colors for each elongate substrate, such as for providing crisp or gradual color transitions. In various embodiments of the method and device of the present subject matter, many colors or other additives can be simultaneously available for application in any desired combination or pattern to each elongate substrate. For example, in various embodiments, greater than six additives, such as greater than six colors, can be simultaneously available for cost-effective on-demand application to each yarn or

elongate substrate, which contrasts with conventional carpet-forming technology in which use of greater than six pre-colored or solution-dyed yarns is generally not technically feasible or financially feasible.

[0014] Various embodiments of a process and device of the present subject matter can simultaneously apply additives such as colors (e.g., the same colors or different colors) to multiple yarns simultaneously. Various embodiments of the present subject matter can simultaneously apply multiple types of additives of each elongate substrate, such as multiple colorants, or such as a combination of one or more colorants and chemical treatments.

BRIEF DESCRIPTION OF THE FIGURES

[0015] FIG. 1 includes a flow diagram illustrating a creel and a grooved transfer drum, in accordance with various embodiments.

[0016] FIG. 2 includes a schematic representation of a grooved transfer drum with inlet and outlet guide rollers, in accordance with various embodiments.

[0017] FIG. 3A includes a schematic representation of a grooved transfer drum viewed on a radial axis, in accordance with various embodiments.

[0018] FIG. 3B includes a schematic representation of a grooved transfer drum viewed on a longitudinal axis, in accordance with various embodiments.

[0019] FIGS. 4A-4D illustrate schematic representations showing groove profiles in a transfer drum, in accordance with various embodiments.

[0020] FIG. 5 illustrates a system in a manufacturing process.

[0021] FIG. 6A illustrates a flow controller, a filament, and a roller, according to one example.

[0022] FIG. 6B illustrates a plurality of flow controllers, a filament, and a roller, according to one example.

[0023] FIG. 6C illustrates a plurality of flow controllers, a filament, a first roller, and a second roller, according to one example.

[0024] FIG. 7 illustrates a view of a segment of a roller and a plurality of flow controllers, according to one example.

[0025] FIG. 8A illustrates a view of a filament, a plate, and a plurality of flow controllers, according to one example.

[0026] FIG. 8B illustrates a view of a filament in a trough and a flow controller, according to one example.

[0027] FIG. 9 illustrates a view of a system, according to one example.

[0028] FIG. 10 illustrates a flow chart of a method, according to one example.

DETAILED DESCRIPTION

[0029] Reference will now be made to certain embodiments of the disclosed subject matter, examples of which are illustrated in part in the accompanying drawings. While the disclosed subject matter is described in conjunction with the enumerated claims, it will be understood that the exemplified subject matter is not intended to limit the claims to the disclosed subject matter.

Process

[0030] A process for applying an additive to an elongate substrate includes contacting the elongate substrate with the trough. A process also includes transferring the additive to the elongate substrate. The transferring can include applying the additive directly to the elongate substrate in the trough, applying the additive directly to the trough and transferring the additive from the trough to the elongate substrate, or a combination thereof. In this document, the terms additive and agent are used interchangeably.

[0031] The elongate substrate can be flexible. The elongate substrate can be at least one of a natural fiber, synthetic fiber, filament, wire, narrow strip, tubing, pipe, conduit, cable, and a yarn. The yarn can include bundles of continuous fiber, staple fiber, or a combination of the two. A yarn can include any suitable number of filaments. A yarn can include any suitable number of plies. The filaments, plies, or a combination thereof, can be twisted or untwisted. The elongate substrate can be carpet yarn. Examples of suitable synthetic fibers include polyamides (including nylon-6,6 and nylon-6) as well as and polyesters and polyolefins. Natural fibers can

be cotton, wool, or silk. An elongate substrate can be fabricated by a process including elongation or it can be fabricated in any other manner in which the finished length dimension is larger than a cross-section dimension (such as a diameter).

[0032] Yarn materials can include polyamides, co-polyamides, polyesters, polyolefins, merely to name a few nonlimiting examples. Polyamides and co-polyamides can include nylon-6, nylon-6,6 nylon-12, and nylon-4,6, with nylon-6,6 being preferred for durability and colorfastness. Suitable polyesters can include PET, PPT and PBT, while suitable polyolefins can include polyethylene and polypropylene, merely to name a few nonlimiting examples.

[0033] A process can include applying additive to two or more strands of yarn in parallel. The disclosed process can include applying additive to yarns that stretch (e.g., in the direction of a central or longitudinal axis) and narrow (e.g., in a radial direction or in a direction transverse to the longitudinal axis of the yarn). These dimensional changes in the yarn can occur during the additive application process.

Additive

[0034] The additive can be any suitable additive. The additive can be or include a colorant, clear ink, a wetting agent, a stain-resist chemical, a water-repellent chemical, or a combination thereof. The additive can include a colorant, such as including any suitable one or more colors. The colorants can include a variety of hues and densities. The colorant can include at least one color selected from the group cyan, magenta, yellow, and black (e.g., CYMK). The colorant can be an ink, a dye, a pigment, or a combination thereof. Herein, when “ink” is referred to, a dye, ink, pigment, or combination thereof, can alternatively be used. A clear colorant (e.g., clear ink) can be used, for example, to adjust the density of the color.

[0035] Suitable colorants include liquids and pastes containing pigments or dyes. Non-limiting examples of the type of inks that can be used include acid dye inks, disperse dye inks, reactive dye inks, sublimation inks, and pigment inks.

Examples of such digital inks are the A700 series for acid dye, D700 series for disperse dye, P700 series for pigment, and R700 series for reactive dye-based inks, marketed by DuPont under the trademark Artistri®. Examples of sublimation inks are Terasil® TS inks from Huntsman Corporation and Elvajet® Coral inks from Sensient Technologies.

[0036] A colorant can include a base carrier, such as a medium in which a dye or pigment is dispersed or dissolved. Depending on the base carrier used, the colorant can be water-based (aqueous), solvent-based, or oil-based. A colorant can also include a surfactant, a humectant, a viscosity modifier, a binder resin, a pH modifier, and other functional chemical, or a combination thereof, as needed. In one embodiment, the colorant is water-based (aqueous).

Trough

[0037] The trough can be continuous or discontinuous. The trough can be in a continuous surface, such as an outer surface of a drum or a belt. The surface can further be selected from a cylindrical surface, an elliptical surface, a cylindrical section and an elliptical section. The trough can be parallel to a continuous direction of the continuous surface (e.g., can be equidistant from a single location on the central axis of the drum or belt). The trough can be in a discontinuous surface, such as a plate. The trough can be in a surface that includes one trough or a plurality of troughs. A trough can have any suitable cross-sectional shape, such as v-shaped, u-shaped, semicircular, star-shaped, square, rectangular, triangular, oval, or a combination thereof. The trough can have a uniform cross-sectional shape, such as a uniform width (e.g., at the top of the trough joining with the surface) and depth (e.g., distance from the top of the trough joining with the surface to the bottom of the trough). The trough can have any suitable width, such as a width of between 0.1 mm and 5 mm. The trough can have any suitable depth, such as 0.5 mm to 3 mm. The trough can be a groove in a surface.

[0038] The cross-sectional shape of the trough can be selected based on various factors such as yarn (substrate) properties, additive (colorant) properties, grooved-surface properties, yarn speed, grooved surface speed, desired yarn tension,

and desired additive level and application uniformity. For example, a cross-section can be selected to optimize the tension of the yarn in the trough, the flow of the colorant in the trough to the yarn, the wetting of the yarn by the colorant, and to control sling-off when the yarn exits the trough. According to one example, with a springy yarn, it may be important to reduce the yarn contact area to the trough to minimize the impact of groove velocity on the yarn tension. In that case, a v-shaped groove may allow less contact than a u-shaped groove as well as provide a small channel for the additive to distribute itself in between the bottom of the yarn and the bottom of the groove. The latter may provide better along-end uniformity. On the other hand, an un-bulked yarn can be treated using a groove contoured to align with the yarn cross-section to provide more contact between the yarn and the groove for good tension control and wetting.

[0039] In one example, the elongate substrate has an irregular or fuzzy surface. The geometric profile or physical properties of the trough can be selected to facilitate application of a colorant, or additive, to the elongate substrate. For example, a trough having a profile that more closely matches the cross section of the substrate will be more efficient in delivering colorant. Thus, a semi-circular profile trough will be more efficient than a rectangular or v-shaped trough, particularly so if the substrate has fuzzy texture.

[0040] A process can include moving the trough along its longitudinal direction and moving the elongate substrate in the same direction of trough movement or counter to the direction of trough movement. Applying the additive directly to the elongate substrate in the trough, or applying the additive directly to the trough, can include selectively controlling the flow of the additive through an additive delivery conduit. A delivery conduit can be coupled to a flow controller, such as a digital print-head, an electro-pneumatic valve, or an electromagnetic valve. A process can include selectively controlling the flow or one or more additives through the flow controller.

[0041] A process can include applying a colorant directly to the elongate substrate in the trough or applying the colorant directly to the trough and transferring the colorant from the trough to the elongate substrate, can include

flowing individual streams of cyan, magenta, yellow, and black colorant to the trough. The flow of the individual streams of colorant through colorant delivery conduits to their application on the elongate substrate or trough can be selectively controlled by at least one selected from digital print-heads, electropneumatic valves, and electromagnetic valves. A process can include controlling the flow of at least two of the colorants through a digital print-head for application directly to the elongate substrate in the trough or for application directly to the trough.

[0042] A process can include positioning at least two of the elongate substrates in separate troughs on the surface and applying the colorant to the at least two elongate substrates or applying the colorant to at least two of the troughs and transferring the colorant from the at least two troughs to the at least two elongate substrates. A process can include applying the colorant to the at least two elongate substrates in different patterns or transferring the colorant from the at least two troughs to the at least two elongate substrates in different patterns.

[0043] A process can include at least partially removing residual colorant from the continuous trough after applying the colorant directly to the elongate substrate in the trough, or after applying the colorant directly to the trough and transferring the colorant from the trough to the elongate substrate. A process can include applying clear colorant (e.g., clear ink) to the grooved transfer drum after applying the colorant directly to the elongate substrate in the trough, or after applying the colorant directly to the trough and transferring the colorant from the trough to the elongate substrate.

[0044] A grooved drum or belt can include a trough (e.g., wherein at least one groove in the drum or belt is the trough). A process can include rotating the grooved drum or belt and moving the elongate substrate in the same direction of drum or belt rotation or counter to the direction of drum or belt rotation. The grooved drum can be driven with a motor driver to rotate. The rotation can be achieved by providing such energy input as electrical, mechanical, pneumatic, hydraulic, renewable, and the like. The rotation mechanism can include speed variation, constant speed, or any combination. Rotation can be in the same direction as the moving yarn or in the opposite direction. The rotational velocity of the drum

and the linear velocity of the yarn can be measured and controlled so that they are the same (e.g., no relative linear motion at the point of contact) or different.

Suitable measurement and control systems include constant speed controllers and constant tension controllers.

[0045] A process can include positioning at least two yarn strands in separate grooves on the grooved drum and applying colorant to the at least two yarn strands in different patterns. One colorant or more than one colorant can be applied to each groove of the grooved drum.

Elongate substrate

[0046] Various embodiments provide an elongate substrate treated via any process or device described herein. The elongate substrate can be a colored elongate substrate. The elongate substrate can be a yarn, such as a carpet yarn.

Device for applying additive to an elongate substrate

[0047] Various embodiments provide a device that can perform a process described herein. An example device for applying additive to an elongate substrate includes a grooved surface including at least one groove. The groove can be a trough. An example device can also include an additive dispenser to selectively apply additive directly onto the elongate substrate or onto a groove of the grooved surface. An example device can further include a guide for holding the elongate substrate in the groove or in contact with additive in a groove of the grooved surface. The additive dispensed by the additive dispenser can be a colorant, or another material, such as a chemical treatment other than colorant.

[0048] The additive dispenser can be any suitable dispenser for applying additive to the elongate substrate in the trough or applying additive to the trough. The additive dispenser can be selected from the group consisting of a digital print-head, electropneumatic valve, and an electromagnetic valve.

[0049] During use of one example of a device, the grooved surface can be stationary or moving, and the elongate substrate can be moving. The grooved surface can move such that the grooved surface and the elongate substrate are

stationary with respect to one another at a point of contact between the two. The grooved surface can be stationary or moving such that the grooved surface and the elongate substrate are moving with respect to one another at a point of contact between the two.

[0050] An example device can include a sensor for measuring the linear velocity of the elongate substrate in relation to the grooved surface at a point of contact between the two. An example device can include a sensor for measuring the linear velocity of the grooved surface, or of the elongate substrate. Elongate substrate linear velocity information can be transmitted from another machine, such as a tufting machine, or software, such as carpet design software. An example device can include a control circuit for controlling the relative linear velocity of the yarn with respect to the grooved surface at a point of contact between the two. An example device can include a feedback or feedforward loop for controlling the relative linear velocity of the yarn and the linear velocity of the grooved continuous surface at a point of contact between the two.

[0051] The grooved surface of an example device can be a continuous surface such as a drum or belt, or a discontinuous surface such as a plate. The grooved surface can include any suitable number of grooves, such as one groove or a plurality of grooves. The grooved surface can be a drum. The drum or belt can include any suitable outside diameter, such as between 6 inches (152 mm) and 36 inches (914 mm). The size of the drum or belt is not critical, and larger drums than specified above can function acceptably well, depending on the economics of a process. The specific ratio of drum or belt length to diameter can be a function of the number of elongate substrates being simultaneously processed. Grooved surfaces having at least two grooves can have a groove to groove spacing (e.g., the space from one groove to the next groove) of between 0.5 mm and 6 mm. The groove can have any suitable cross-sectional shape, such as v-shaped, u-shaped, semicircular, star-shaped, square, rectangular, triangular, oval, or a combination thereof. The groove can have a uniform cross-sectional shape, such as a uniform width (e.g., at the top of the trough joining with the surface) and depth (e.g., distance from the top of the trough joining with the surface to the bottom of the

trough). The groove can have any suitable width, such as a width of between 0.1 mm and 5 mm. The trough can have any suitable depth, such as between 0.5 mm and 5 mm. The trough can be a trough in the surface.

[0052] The grooved surface (e.g., the location at which the additive contacts the groove or contacts the elongate substrate in the groove) and an outlet of the additive disperser can have any suitable spacing therebetween, such as between 0.1 mm and 5 mm.

[0053] FIG. 1 is a schematic representation of an embodiment of a rotating grooved drum assembly. For example, yarns can be passed over a grooved drum or contacted with another form of grooved surface. Suitable grooved surfaces can be stationary or can move (e.g., rotate) at a desired speed, which can be set at a constant or which can be controlled by a processor or a control circuit.

[0054] As shown schematically in FIG. 1, a 25-yarn creel can be combined into a beam and guided through a series of guide rollers into each groove on the drum. Each yarn is placed in a separate groove and guided such so that the color of each yarn can be applied and controlled independently. Spacing between grooves is maintained about the same as the desired spacing between the yarns required in the downstream process steps, such as tufting or space-dyeing.

[0055] FIG. 1 illustrates system 100A. System 100A can include a color applicator having a digital print-head, an electromagnetic valve, or a micro-dispensing device. One or more flow controllers, such as a color applicator (e.g., colorant dispensers) are placed above the grooved drum or surface and can be moved to align with the yarn running through each groove. In the example of FIG. 1, system 100A includes creel 110 having carriers 115A, 115B, 115C, 115D, and 115E. In this example, each carrier 115A, 115B, 115C, 115D, and 115E includes five spools, each spool configured for delivering a filament to a guide on beam 20. The filaments are routed via guides, such as guide 120 to conveyor 150A. A conveyor, such as conveyor 150A, can include a drum, a roller, or a plate. A filament, such as filament 90, is guided to travel about conveyor 150A in the direction shown by arrow 40A. Conveyor 150A, shown here in the form of a drum, rotates about longitudinal axis 30. System 100A includes a plurality of flow

controllers, here denoted as flow controllers 130A, 130B, 130C, 130D, and 130E. In one example, flow controllers 130A, 130B, 130C, 130D, and 130E are aligned with a trough or groove about the circumference of conveyor 150A in one-to-one relation. In one example, more than one flow controller, such as flow controllers 130A, 130B, 130C, 130D, and 130E, are aligned with a trough or groove about the circumference of conveyor 150A. For example, flow controllers 130A and 130B are aligned with a first groove and flow controllers 130C, 130D, and 130E are aligned with a second groove.

[0056] The spatial distance (e.g., gap) between print-heads and the drum surface can be in the 0.1 mm to 5 mm range. The gap dimension can be adjusted depending on a process being run. When digital print-heads are used, one or more print-heads can be used in sequence to apply primary colors/inks, for example, cyan (C), magenta (M), yellow (Y), black (K), and the like. The print-heads configuration can be set to CMYK, CYMK, MCKY, CCMMYYKK, or any suitable combination depending on the desired coloration performance. There is no limit on the number of color inputs used and the print-heads can have more than four color inputs. In one embodiment, the print-heads can include a clear ink to clean the drum surface or balance moisture content in printed yarn. In another embodiment, a wetting agent can be applied through a print-head.

[0057] The grooved drum or surface can guide (e.g., mechanically stabilize) multiple yarns while at the same time providing a reservoir to contain the color(s) applied to each yarn. In one example, the surface including the groove or trough (e.g., transfer surface) is a drum (e.g., transfer drum) and the drum rotational speed can be controlled to match the yarn movement speed, or it can be different. Differential speed between yarn and the drum can also be maintained as a means to control the yarn tension.

[0058] A print-head can be programmed to color a yarn independent of other yarns and in a selectable color and pattern. In one embodiment, colors are applied on the top of the yarn. In another embodiment, a plurality of ink colors is injected into the drum grooves and then this mixture of inks can be picked up by the moving yarn.

[0059] In one embodiment, a 12-inch (30.48 cm) diameter drum is used and it is sufficiently long to include multiple grooves at a reasonable spacing, such as 2.5 mm. A 25-yarn creel (e.g., a rack for holding bobbins or spools) can be used with a beam or parallel sheet of yarns and guided through a series of guide rollers into each groove on the drum.

[0060] The cross-sectional shape of a transfer device can vary, and any form of a grooved surface can be suitable. For example, the surface can include a cylindrical drum, and the cylinder can have a circular or elliptical cross-section. A transfer device can be conical, and the grooves can be parallel to one another or can form pitched screw threads.

[0061] The material of construction of a transfer device can be metallic, non-metallic, plastic, composite, wooden, ceramic, or any combination that is suitable to provide sturdy and stable operation.

[0062] FIG. 2 is a schematic representation of example assembly 201 according to the present disclosure. In FIG. 2, assembly 201 includes conveyor 150B having a plurality of grooves, some of which are denoted here as groove 23A, 23B, and 23C, around a circumference. While eight such grooves are shown in FIG. 2, there is no limit as such. The drum length can be chosen depending on the total number of grooves. The conveyor 150B diameter can be in the 6 inches (152 mm) to 36-inch range (914 mm). A drum with a larger diameter can be suitable as described herein. Depending on the total number of yarns to be processed and the desired spacing between the yarns, the drum length can be sufficient to house as many grooves as required and with reasonable spacing in-between neighboring grooves. Guide rollers 120 are schematically shown and the location, orientation, and inclination can be varied depending on practicality, processing, and desired yarn tension across the drum. Assembly 201 can be used to process a filament, such as filament 90 shown here. An individual yarn can be continuously processed by the grooved drum. The drum can rotate in a clockwise or counter-clockwise direction or can be stationary. Individual yarns move over the drum through individual grooves either in the same direction or opposite direction of the drum rotation. In one example, filament travel is shown by arrow 40B. In one example, filament

travel is opposite that direction shown by arrow 40B. (Conveyor 150B can remain fixed or rotate in either direction.)

[0063] FIG. 3A includes a schematic representation of grooved transfer conveyor 150C viewed on a radial axis relative to longitudinal axis 30, in accordance with one embodiment. In the figure, the grooved conveyor illustrates some of a plurality of individual grooves with each groove aligned with a guide 120. FIG. 3B includes a schematic representation of grooved transfer conveyor 150C viewed on longitudinal axis 30, in accordance with one embodiment. In the figures, conveyor 150C is shown to have eight grooves, two of which are denoted here as groove 23D and groove 23E. Filament 90 is routed via guide 120 to engage with groove 23E.

[0064] FIG. 4A illustrates a portion of conveyor 150D having groove 23F. Groove 23F has a profile that can be described as trapezoidal. FIG. 4B illustrates a portion of conveyor 150E having groove 23G. Groove 23G has a profile that can be described as rectangular. FIG. 4C illustrates a portion of conveyor 150F having groove 23H. Groove 23H has a profile that can be described as triangular. FIG. 4D illustrates a portion of conveyor 150G having groove 23J. Groove 23J has a profile that can be described as semicircular.

[0065] The drum grooves can be of any desired cross-sectional shape, such as and not limited to, semicircular, square, rectangular, triangular, oval, v-shaped, and star-shaped, merely to name a few nonlimiting examples. The groove shapes can be selected based on the yarn type, cross-section, thickness, drum machinability, or a combination thereof. A groove shape can provide more uniform color than other choices for a given yarn.

[0066] On the drum, groove-to-groove spacing can be any suitable distance. For many carpet yarns, distances in the range of 1 mm to 6 mm range are suitable. Depending on the application, longer groove-to-groove spacing can be satisfactory, but if not required for technical reasons, could produce a sub-optimal result in terms of footprint and cost. The groove width at the drum outer surface (or perimeter) can similarly be any suitable width as dictated by the elongate substrate to be colored, with most carpet yarns accommodated by groove widths in the range of 0.1 mm to 5

mm. The groove depth can similarly be selected depending on the yarn to be processed and can range between 0.5 mm and 5 mm.

[0067] If the colorant is applied to the transfer drum or to the yarn using a print-head, then any suitable print-head can be used. The print-head can be drop-on-demand or continuous type. Non-limiting examples of print-heads can include drop-on-demand piezo type, drop-on-demand thermal type, drop-on-demand electrostatic type and electromagnetic valve-jet, merely to name a few. Other types of micro-dispensing devices can also be used.

[0068] FIG. 5 illustrates system 500A in a manufacturing process. System 500A includes an arrangement of creel 510, agent delivery module 520, dryer 530, and tufter 540. System 500A can be configured for manufacturing carpet or a textile product fabricated using filaments having a variety of coatings or colors. Creel 510 can include a filament delivery system for providing any number of individual filaments. Creel 510 can include a motor drive unit, a tensioner, a guide, a spool, and other elements for delivering a filament or a plurality of individual filaments. Agent delivery module 520 can include a drum or plate or other device having a trough or groove, a flow controller, a processor, and guide elements to direct travel of one filament or a plurality of filaments. Dryer 530 can include a heater element or optical treatment element for curing or treating an agent. Tufter 540 can include machinery to form tufts of filaments such as found in carpet manufacturing.

[0069] FIG. 6A illustrates flow controller 130F, filament 90, and conveyor 150H, according to one example. In this example, flow controller 130F is configured to deliver an agent on filament 90 at a time when filament 90 is positioned in a groove of conveyor 150H. Arrow 40C indicates a direction of rotation of conveyor 150H. Filament 90 can be viewed as traveling in a complementary direction or in opposition to conveyor 150H rotation.

[0070] FIG. 6B illustrates flow controllers 130G and 130H, filament 90, and conveyor 150J, according to one example. In this example, flow controller 130G is configured to deliver a first agent to a groove of conveyor 150J and flow controller 130H is configured to deliver a second agent to a groove of conveyor 150J. First

agent and second agent can differ or can be the same material. Arrow 40D indicates a direction of rotation of conveyor 150J. Filament 90 can be viewed as traveling in a complementary direction or in opposition to conveyor 150J rotation.

[0071] FIG. 6C illustrates flow controllers 130J and 130K, filament 90, conveyor 150K, and conveyor 150L, according to one example. In this example, flow controller 130J is configured to deliver a first agent to filament 90 positioned in a groove of conveyor 150K and flow controller 130K is configured to deliver a second agent to a groove of conveyor 150L. First agent and second agent can differ or can be the same material. Arrow 40E indicates a direction of rotation of conveyor 150K. Arrow 40F indicates a direction of rotation of conveyor 150L. Filament 90 can be viewed as traveling in a complementary direction or in opposition to conveyor 150K rotation or conveyor 150L rotation.

[0072] FIG. 7 illustrates an axial view of a segment of conveyor 150M and flow controllers 130L, 130M, 130N, 130P, 130Q, and 130R, according to one example. In the figure, flow controllers 130L, 130M, 130N, 130P, 130Q, and 130R can be viewed as aligned on a single groove of conveyor 150M or can be viewed as aligned on a plurality of grooves of conveyor 150M. The flow controllers are arranged at radial positions about an axis of conveyor 150M. In the figure, radials 70A and 70B are marked to indicate angular displacement α about which flow controllers 130Q and flow controller 130R are positioned. A plurality of flow controllers can be disposed along a single radial or distributed about a plurality of radials relative to an axis of a roller. In one example conveyor 150M represents a curved plate having a groove.

[0073] FIG. 8A illustrates a view of filament 90, conveyor 150N, and flow controllers 130S and 130T, according to one example. Filament 90 is guided in a groove of conveyor 150N and travels relative to fixed positions of flow controllers 130S and 130T. Flow controller 130S provides a first agent and flow controller 130T provides a second agent. The first agent and the second agent can be the same or different.

[0074] FIG. 8B illustrates a view of filament 90 in trough 23K of conveyor 150P along with flow controller 130U, according to one example. Filament 90 is

shown at a position resting on the bottom of trough 23K and trough 23K is shown having a trapezoidal profile. The view illustrates agent droplet 80 emerging from flow controller 130U at a time before filament 90 is treated. In one example, droplet 80 is applied to trough 23K and at a time thereafter, filament 90 is conveyed in trough 23K and treated with the agent.

[0075] FIG. 9 illustrates a view of system 900, according to one example. System 900 includes filament supply 910, agent delivery module 920, uptake module 930, network interface 940, processor 950, user interface 960, and memory 970. System 900 can be configured for manufacturing carpet, garments, textile products or other materials in which a filament is treated with an agent. Filament supply 910 can include a creel, a spool of filament 90, a tensioner, a drive unit, or other elements for delivering filament 90 to downstream processes. Agent delivery module 920 can include a conveyor having a groove and a flow controller. Uptake module 930 can include a finisher, a dryer, a tufter, a winder, or other downstream process machinery. Processor 950 can include an analog processor, or a digital processor configured to monitor or control operation of system 900. Network interface 940 can include a wired or wireless interface to a communication network or data network. User interface 960 can include input devices such as touch pad, a keyboard, a mouse, a touchscreen and an output device such as a printer, a display screen, an audio device, and indicator light. Memory 970 can include a random-access memory or hard drive and can provide storage for data or instructions for execution by processor 950.

[0076] Processor 950 can be coupled to various elements in the system shown here. Processor 950 can be configured to receive sensor data. Sensor data can be derived from sensors coupled to elements of system 900. For example, processor 950 can be configured to receive filament 90 information such as speed, acceleration, temperature, or tension and configured to control delivery of an agent in accordance with instructions stored in memory 970, instructions received via network interface 940, or instructions received via user interface 960.

[0077] The connections between any of the elements of system 900 can be wired or wireless.

[0078] In one example, processor 950 executes control using a feedback loop in which an excursion of a measured parameter is met with adjustment of a control parameter. In one example, processor 950 executes a feedforward control framework in which an input parameter is specified without regard to error-based adjustments.

[0079] Elements of system 900 can be separately or collectively addressable. For example, operation of a groove (such as direction or speed of relative movement) or movement of a filament, or discharge from a flow controller, is controlled independent of other operational parameters.

[0080] FIG. 10 illustrates a flow chart of method 1000, according to one example. Method 1000 can be configured to treat a filament with an agent. At 1010, method 1000 includes moving a filament in a trough. In one example, the filament can travel relative to a stationary trough. In one example, the filament can be stationary, and the trough can move, or be dynamic. In one example, both the filament and the trough can be dynamic. The trough can be a feature of a conveyor such as drum, a roller, or a plate.

[0081] At 1020, method 1000 includes delivering an agent to a filament. The agent can be delivered by a flow controller. The agent can be delivered directly to the filament in the trough or the agent can be delivered to the trough and thereafter applied to the filament disposed in the trough.

[0082] At 1030, method 1000 includes removing the filament from the trough. This can include repositioning the conveyor having the trough or can include repositioning the filament relative to fixed position of a conveyor.

Filament

[0083] A filament can include an elongate substrate or material having a generally longitudinal axis. A dimension of the longitudinal axis of a filament is substantially greater than a radial dimension. A filament can be flexible and can be elastic in a direction parallel with the longitudinal axis or elastic in a direction aligned with a radial dimension. Example materials for a filament can include a

fiber, yarn, wire, a narrow strip, pipe, conduit, or a cable. A filament can include a natural material or a synthetic material.

Agent

[0084] An agent can be a liquid, a gel, or a gas having fluid-like properties. An agent can include an additive such as a colorant, a dye, or an ink. An agent can be clear or colored. An agent can be selected to balance moisture or selected to provide cleaning or washing. An agent can include water or a solvent. An agent can include a wetting agent.

[0085] The agent can be applied to a trough and the filament can be conveyed in the trough. The agent can be applied to a filament traveling in the trough in which case the filament can be guided by the trough.

[0086] The trough can be stationary or dynamic. A stationary trough can be a feature of a curved plate or of a curved surface. A dynamic trough can be an aspect of a drum, a wheel, a roller, or a belt. The trough can be in the outer surface of a drum or roller or other form of conveyor. The trough can be segmented in the manner of lands and valleys in a toothed wheel or drum. In one example, a trough is continuous and has an extent that encircles a drum, roller, or wheel. In one example, a drum has a uniform diameter along a longitudinal axis. In one example, a drum has a conical profile along a longitudinal axis. In one example, the trough is finished with a plurality of micro-pores in which the agent can be carried in the micro-pores. In one example, the conveyor includes a platen roller.

[0087] The rotary speed and direction of the conveyor can be processor-controlled. The dimension of the conveyor can be selected for a particular application. For example, the diameter, length, groove pitch, groove dimensions, and groove profile can be tailored to suit a manufacturing operation. In one example, a conveyor includes a plurality of grooves distributed along a longitudinal axis of a drum in which a first groove is independent of a second groove. In one example, a continuous groove encircles a drum in the manner of a machine thread. The grooves of a drum can be in the manner of a single-start machine thread or a multi-start machine thread.

[0088] The drum can be fabricated of various materials. The drum can be coated or finished with a material suited for a manufacturing operation.

[0089] The drum can be driven by a motor, such as a motor powered by electric, hydraulic, or pneumatic power. The direction of rotation of a drum can be controlled. In one example, the direction and speed are controlled by a processor. The direction of rotation can be viewed as antegrade or retrograde relative to filament travel. The drum rotation speed and the filament travel speed can be matched or can be different (such as one greater or less than the other). In one example, the drum is free-wheeling and can be configured with a brake mechanism to control filament tension.

Flow controller

[0090] The flow controller can be in the form of a print-head of various types. For example, an electrically operated flow controller can include an electrically operated diaphragm that controls ejection of a droplet of an agent. The flow controller can be operated electrically, pneumatically, mechanically, or hydraulically.

[0091] A groove can be configured with a single flow controller in one-to-one relation or a single groove can be configured with a plurality of flow controllers. A plurality of flow controllers can be distributed about a drum with variable spacing and configured for placement of agent at a variety of radial positions about a drum.

[0092] A flow controller can deliver an agent to a filament or to a groove via a conduit. The conduit can be valve-controlled. In one example, the flow controller is directly coupled to a groove. The flow controller can be processor-controlled.

[0093] “Bulked discontinuous elongate substrate” means a geometry where the structure to be colored is continuous in the direction of travel (the “Z” direction) and discontinuous normal to the direction of travel (the “X” and/or “Y” directions), for example, a sheet of parallel bulked carpet yarns being fed to a tufting machine.

[0094] In an embodiment, the colorant flow controller can be a digital inkjet printhead. Digital inject printheads are generally unsuitable for directly printing a

discontinuous substrate such as a threadsheet of parallel yarns. For example, the nozzles of certain digital printheads are not accurate enough to impinge ink selectively onto a desired yarn in a threadsheet while not impinging ink in the spaces between yarns. Thus ink between the yarns would be wasted (and would build up creating operational problems). Thus a printhead design for a continuous substrate generally cannot be used with a discontinuous substrate. In one embodiment, the disclosed method and apparatus solves this problem by allowing printheads suitable for use with continuous substrates to be used with a discontinuous substrate by redirecting the ink via grooves, for example on a roller or a stationary device. In an embodiment, the colorant control device can be a single-pass fabric printer and the colorant is transferred first to a grooved roll and then to threadsheet of parallel carpet yarns.

[0095] In other embodiments, the disclosed method and apparatus colors yarns individually. These embodiments overcome size (footprint) limitations of other methods of coloring individual moving yarns. Specifically, one limitation of previously known methods of coloring individual moving yarns in a threadsheet is that application devices can be too wide to treat individual yarns. For example, to impart colorant sets of individual yarns (ranging from a twenty-end (*i.e.*, twenty-yarn) device up to and including a six-foot wide tufting machine) could require a prohibitively large form factor (footprint). The grooved roll combination as described herein at least partially mitigates this problem of available footprint.

[0096] Coloring low-bulk or no-bulk moving yarns (such as embroidery or sewing thread) presents different technical problems than coloring bulked yarns. These devices rely on precise placement of yarns, high tension of yarns and color application from nozzles at different angles around the yarn. Bulky yarns are stretchy, porous and hard to handle and print. Strategies that work for low-bulk or no-bulk yarns do not work acceptably well for bulked yarn because at high tensions the bulked yarn is too deformed to receive colorant uniformly and the colorant does not penetrate uniformly.

[0097] In various embodiments, the disclosed method and apparatus solve these problems by selectively transferring colorant to a grooved roll (using

conventional digital printhead technology) and then redirecting the ink streams via the grooves to the discontinuous yarn substrate, especially to a threadsheet of bulked carpet yarn being fed to a tufting machine.

[0098] In an embodiment, the disclosed process overcomes the problem of requiring a non-aqueous ink with an externally applied electrostatic charge and operates in the absence of externally applied electrostatic charge. In an embodiment, the disclosed process uses aqueous inks.

[0099] Throughout this document, values expressed in a range format should be interpreted in a flexible manner to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. For example, a range of “about 0.1% to about 5%” or “about 0.1% to 5%” should be interpreted to include not just about 0.1% to about 5%, but also the individual values (e.g., 1%, 2%, 3%, and 4%) and the sub-ranges (e.g., 0.1% to 0.5%, 1.1% to 2.2%, 3.3% to 4.4%) within the indicated range. The statement “about X to Y” has the same meaning as “about X to about Y,” unless indicated otherwise. Likewise, the statement “about X, Y, or about Z” has the same meaning as “about X, about Y, or about Z,” unless indicated otherwise.

[00100] In this document, the terms “a,” “an,” or “the” are used to include one or more than one unless the context clearly dictates otherwise. The term “or” is used to refer to a nonexclusive “or” unless otherwise indicated. The statement “at least one of A and B” has the same meaning as “A, B, or A and B.” In addition, it is to be understood that the phraseology or terminology employed herein, and not otherwise defined, is for description only and not of limitation. Any use of section headings is intended to aid reading of the document and is not to be interpreted as limiting; information that is relevant to a section heading may occur within or outside of that section.

[00101] In the methods described herein, the acts can be carried out in any order without departing from the principles of the subject matter, except when a temporal or operational sequence is explicitly recited. Furthermore, specified acts

can be carried out concurrently unless explicit claim language recites that they be carried out separately. For example, a claimed act of doing X and a claimed act of doing Y can be conducted simultaneously within a single operation, and the resulting process will fall within the literal scope of the claimed process.

EXAMPLES

[00102] The denier of a fiber is the mass in grams per 9000 meters of the fiber.

Example 1

[00103] 240 packages of two-ply nylon-6,6 yarn, denier 2490, 128 filaments, 4.5 twists per inch (tpi) (or 1.77 twists per cm), are placed on the creel of a tufting machine to produce a 24-inch (60.96 cm) wide carpet having a desired color design. The color application device is installed between the creel and the tufting machine. Each yarn is guided and placed in a separate groove of the drum 21 as in FIG. 2. One example includes one single package of yarn per groove. For example, FIG. 1 illustrates a side view of a threadsheet that goes into the page. In this example, yarn speed is maintained at 22 meters/min. The grooved drum 21 surface rotates at the same speed as the yarn speed. In one example, a total of twelve drop-on-demand inkjet print-heads are installed and aligned above the twelve grooves atop of the drum. The example of FIG. 2 illustrates eight grooves and an example as depicted in FIG. 3 includes any number of grooves as signaled by the image break lines and corresponding vertical ellipse symbol. In one example, the package is 2-ply and there are 240 grooves to receive the yarn with one groove per yarn. Three print-heads are used for each of the base ink colors cyan, magenta, yellow, and black. Print-heads are programmed and integrated with the design software to deliver inks to create the desired carpet pattern. The ink amount and time of applying the ink is determined by the design software which controls and monitors each individual print-head. Ink is directly applied to the yarns as they are channeled through the grooves and under the print-heads. After the yarns are colored, they pass through an ink drying and fixation unit before being fed to the tufting machine. All yarns are

colored independently with different colors as they are fed to the tufting machine. Color is also varied along the length of the same yarn to achieve a desired design pattern in the carpet. Consider an example having 240 grooves. A print head has a certain width depending on the design. Assume an example of a 1/10" gauge spacing of yarn sheet and grooves. One print head design includes a single row of 256 nozzles, evenly spaced over 2.25". Thus, there are an average of 11.37 nozzles approximately lined up with each groove. In an example having drop-on-demand nozzles, the system can be configured to not fire the nozzles that line up with the divider between two grooves. Consider an example in which each groove has at least 9 nozzles lined up with it for application. Assume each print head has only one color. Therefor multiple rows of printheads can be activated to apply a combination of colors to get a specified mixed color. Multiple rows of print heads can be activated to deliver sufficient ink to provide to the threadlines to achieve a particular color. Multiple rows of print heads can have the same color or different colors. For example, if there are three print heads per each color, then each color can use up to $9 \times 3 = 27$ nozzles to squirt ink to a single threadline in a single groove. The groove cross-sectional shape can be configured to accommodate multiple print heads at the midpoint between two grooves. For example, a very sharp edge can facilitate cleanly separating two nearby adjacent flows of colorant from nearby or adjacent nozzles. In some examples, a broad profile can be used. A sharp profile may also assist in aligning the grooved roll with the printheads so that all the nozzles are aligned with their intended groove.

Example 2

[00104] 1152 packages of two-ply nylon-6,6 yarn, denier 2640, 136 filaments, twist 4.0 tpi (or 1.57 twists per cm), are placed on the creel of the tufting machine to produce a 12-feet wide carpet having a desired color design. The basic equipment setup is similar to that used in Example 1 except the grooved drum is configured with 1152 grooves and the length is increased accordingly to accommodate higher number of yarns.

Example 3

[00105] The Example 2 procedure is employed except that an additional set of three print-heads is installed to apply “clear” ink to remove ink residue from the drum surface and to keep it clean. The inks penetrate into the surface due to chemical affinity of the yarn substrate. There may be excess ink that does not penetrate but is needed initially to provide a concentration gradient into the yarn. Then adding a liquid to remove it prevents later rub-off in the process or in end use insults such as crocking (rubbing).

[00106] In one example, each row of print heads is installed at a circumferential position around the groove drum. Thus, one would continue on around the drum.

Example 4

[0100] 24 packages of single ply nylon-6,6 yarn, denier 1245, 64 filaments, are placed on a creel for space-dyeing. The color application device according to this disclosure is installed between the creel and the winder. Each yarn is guided and placed in a separate groove of the drum. Yarn speed and grooved drum surface speed are both set to 50 meters/min. A total of ten drop-on-demand inkjet print-heads are installed above the grooved drum. Two print-heads are used for each of the base ink colors cyan, magenta, yellow, and black. A set of two print-heads is used to apply a fifth ink color, orange, as a spot color. Print-heads are programmed and integrated with the design software to deliver the desired yarn color pattern. Ink is directly applied (e.g., printed) to the yarns. After yarns are colored, they are passed through an ink drying and fixation unit before winding.

Example 5

[0101] The Example 4 procedure is employed except that ink is not directly applied to the yarns in this case. Ink of all base colors (CMYK) is first deposited (printed) into the respective groove of the drum and then the corresponding yarn is brought in contact with mixed ink. Color transfer occurs via direct contact of the

yarn with the deposited color in the groove. The yarn speed and drum rotation are maintained to obtain the desired ink coloration of the yarn.

Example 6

[0102] The Example 1 procedure is employed except that two grooved drums are used instead of just one. Two drums are arranged close to each other so that color is applied on one side of yarn using the first drum and then color is applied on the other (opposite) side of the yarn using the second drum. Color uniformity is improved with a two grooved drum arrangement.

Example 7

[0103] The Example 1 procedure is employed except that a stationary curved plate with grooves is used in place of the grooved drum. Different yarns moved at different speeds according to the design of a multi-level loop carpet.

Example 8

[0104] The Example 1 procedure is employed except that the FIG. 2 assembly is used to accomplish stain-resist chemical treatment.

[0105] 240 packages of two-ply nylon-6,6 yarn, denier 2490, 128 filaments, 4.5 twists per inch (tpi) (or 1.77 twists per cm), are placed on the creel of a tufting machine to produce 24-inch (60.96 cm) wide carpet. The stain-resist chemical treatment application device is installed between the creel and the tufting machine. Each yarn is guided and placed in a separate groove of the drum 21 as in FIG. 2. In this example, yarn speed is maintained at 22 meters/min. The grooved drum 21 surface rotates at the same speed as the yarn speed. All yarns are treated with the stain-resist chemical independently as they are fed to the tufting machine. Many chemicals besides colorant are jettable. It is a matter of adjusting their viscosity, surface tension, etc. so that the jetting mechanism works properly. This allows very precise metering of chemicals, such as stain-resist chemical, onto the yarn.

Example 9

[0106] The Example 8 procedure is repeated using the FIG. 2 assembly except a water-repellent chemical treatment is applied to the yarns. All yarns are treated with the water-repellent chemical independently as they are fed to the tufting machine.

Example 10

[0107] This Example uses a curved plate to transfer colorant to yarn. In one example, 720 packages of two-ply nylon-6,6 yarn, denier 2500, 128 filaments, twist 4.5 tpi (or 1.77 turns per cm), are placed on the creel of the tufting machine to produce a 6-feet wide carpet on a 1/10th gauge tufting machine. The basic equipment setup is similar to that of Example 1 except the grooved drum is replaced with a curved stationary plate and is configured with 720 grooves and the plate length is sized accordingly to accommodate higher number of yarns. The associated components are adjusted accordingly for mechanical alignment. For the purpose of this example, the grooved plate has a surface that is sufficiently smooth, non-absorptive and wear-resistant. In various examples, the grooved plate is fabricated of a hardened metal surface, includes a ceramic-coated element, or includes solid ceramic rollers. In this example, the plate includes stainless steel, such as a stainless steel alloy known as 316.

[0108] Yarn is pretreated with a wetting agent before passing through a coloration process. Pure water, or a solution of commercially available wetting agent, can be used. The concentration of wetting agent in the solution can be 1-2 grams per liter. A prewetting solution can be applied to the yarn by dipping through or by using a metering pump and an applicator or some other fluid delivery system. Water content in the yarn after prewetting is in the range of 5-50% based on dry weight of yarn being fed per unit time. Each individual yarn is then passed over the slightly curved plate containing grooves with one yarn per groove. The grooved plate remains stationary. Yarn speed is controlled between 10 meters/minute and 30 meters/minute, and can be adjusted as needed based on tufting speed and the carpet design. Twelve rows of printheads (such as Starfire SG1024LA, type drop-on-demand piezo) are positioned above the grooved plate. The long axes of each

printhead (and each row of printheads) is aligned perpendicular to the direction of the yarn movement to achieve sufficient ink flow per yarn. Each printhead is configured to apply ink to up to 25 yarns by directing ink from its selected nozzles into their associated grooves. Ink is directly applied to the yarns as they are channeled through the grooves and under the print-heads. After the yarns are colored, the yarns pass through an ink drying and fixation unit before being fed to the tufting machine. All yarns are colored independently with different colors as they are fed to the tufting machine. Color can be varied along the length of a selected yarn to achieve a desired design pattern in the carpet. Printheads, curved plate, drying and curing system can be provided as a plurality of modular sections having dimensions suited to provide access for operation and maintenance. Cyan, Magenta, Yellow and Black sublimation inks can be used in two different concentrations to cover wide color gamut. Standard concentration can be used in one set of printheads and the lower concentration in the other set of printheads. Some spot colors can be used in other printheads to achieve desired colors. Print-heads can be programmed and integrated with the design software and the tufting machine to deliver inks to create the desired carpet pattern. The ink amount and time of applying the ink is determined by the design software which controls and monitors each individual print-head.

[0109] In one example, the curved plate is devoid of a groove. In this example, individual print-head nozzles and their spray pattern for each individual yarn are configured to deliver colorant to a yarn supported by a plate having a smooth surface. The yarns are guided over the curved plate by other guide elements such as rollers and fairleads and not by a groove in the curved plate.

Example 11

[0110] In this example a system similar to Example 10 is used and is modified to include an individual yarn accumulator between the coloring unit and the tufting machine. The yarn accumulator is configured to average out the yarn speed over time and enables running constant yarn speed for a yarn as it passes through coloration, drying and curing steps.

Example 12

In this example a system similar to Example 10 is used and is modified to include an air-jet after applying prewetting solution to the yarn. Air-jet helps distribute the prewetting solution uniformly on the yarn. In this example, an air-jet sufficiently large to allow passage of the yarn is used. Supply air pressure is maintained at 5psi. Orifice size and supply air-pressure are adjusted to achieve desired moisture content.

[0111] The terms and expressions that have been employed are used as terms of description and not of limitation, and there is no intention in the use of such terms and expressions of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the embodiments of the present subject matter. Thus, it should be understood that although the present subject matter has been specifically disclosed by specific embodiments and optional features, modification and variation of the concepts herein disclosed may be resorted to by those of ordinary skill in the art, and that such modifications and variations are considered to be within the scope of embodiments of the present subject matter.

Embodiments

[0112] The following embodiments are provided, the numbering of which is not to be construed as designating levels of importance:

[0113] Embodiment 1 provides a process for applying an additive to an elongate substrate, a process comprising contacting the elongate substrate with the trough; and transferring the additive to the elongate substrate, the transferring comprising applying the additive directly to the elongate substrate in the trough, applying the additive directly to the trough and transferring the additive from the trough to the elongate substrate, or a combination thereof.

[0114] Embodiment 2 provides a process of Embodiment 1, wherein a process comprises applying the additive directly to the trough and transferring the additive from the trough to the elongate substrate.

[0115] Embodiment 3 provides a process of any one of Embodiments 1-2, wherein a process comprises applying the additive directly to the elongate substrate in the trough.

[0116] Embodiment 4 provides a process of any one of Embodiments 1-3, wherein the additive comprises a colorant, clear ink, a wetting agent, a stain-resist chemical, a water-repellent chemical, or a combination thereof.

[0117] Embodiment 5 provides a process of Embodiment 4, wherein the additive comprises a colorant.

[0118] Embodiment 6 provides a process of Embodiment 5, wherein the colorant is an ink or dye.

[0119] Embodiment 7 provides a process of any one of Embodiments 4-6, wherein the colorant comprises at least one color selected from the group cyan, magenta, yellow, and black.

[0120] Embodiment 8 provides a process of any one of Embodiments 1-7, wherein the elongate substrate comprises at least one of a natural fiber, synthetic fiber, filament, wire, narrow strip, tubing, pipe, conduit, cable, and a yarn.

[0121] Embodiment 9 provides a process of any one of Embodiments 1-8, wherein the elongate substrate comprises a yarn.

[0122] Embodiment 10 provides a process of any one of Embodiments 1-9, wherein the elongate substrate comprises carpet yarn.

[0123] Embodiment 11 provides a process of any one of Embodiments 1-10, wherein the elongate substrate comprises a polyamide, polyester, polyolefin, or a combination thereof.

[0124] Embodiment 12 provides a process of any one of Embodiments 1-11, wherein the trough is in a continuous surface.

[0125] Embodiment 13 provides a process of Embodiment 12, wherein the continuous surface is an outer surface of at least one selected from drums and belts.

- [0126] Embodiment 14 provides a process of any one of Embodiments 12-13, wherein the trough is parallel to a continuous direction of the continuous surface.
- [0127] Embodiment 15 provides a process of any one of Embodiments 1-14, wherein the trough is in a plate.
- [0128] Embodiment 16 provides a process of any one of Embodiments 1-15, wherein the trough is in a surface that comprises more than one trough.
- [0129] Embodiment 17 provides a process of any one of Embodiments 1-16, wherein the trough has a cross-sectional shape that is v-shaped, u-shaped, semicircular, star-shaped, square, rectangular, triangular, oval, or a combination thereof.
- [0130] Embodiment 18 provides a process of any one of Embodiments 1-17, wherein the trough has a uniform width and depth.
- [0131] Embodiment 19 provides a process of any one of Embodiments 1-18, wherein the trough has a width of 0.1 mm to 5 mm.
- [0132] Embodiment 20 provides a process of any one of Embodiments 1-19, wherein the trough has a depth of 0.5 mm to 5 mm.
- [0133] Embodiment 21 provides a process of any one of Embodiments 1-20, wherein the trough has a depth of 1 mm to 3 mm.
- [0134] Embodiment 22 provides a process of any one of Embodiments 1-21, further comprising moving the trough along its longitudinal direction and moving the elongate substrate in the same direction of trough movement or counter to the direction of trough movement.
- [0135] Embodiment 23 provides a process of any one of Embodiments 1-22, wherein the trough comprises a groove.
- [0136] Embodiment 24 provides a process of Embodiment 23, wherein a grooved drum or belt comprises the trough.
- [0137] Embodiment 25 provides a process of Embodiment 24, further comprising rotating the grooved drum or belt and moving the yarn in the same direction of drum or belt rotation or counter to the direction of drum or belt rotation.

[0138] Embodiment 26 provides a process of any one of Embodiments 1-25, wherein applying additive directly to the elongate substrate in the trough, or applying the additive directly to the trough, comprises selectively controlling the flow of the additive through at least one selected from a digital print-head, electropneumatic valve, and an electromagnetic valve.

[0139] Embodiment 27 provides a process of any one of Embodiments 5-26, wherein applying the colorant directly to the elongate substrate in the trough or applying the colorant directly to the trough and transferring the colorant from the trough to the elongate substrate, comprises flowing individual streams of cyan, magenta, yellow, and black colorant to the trough.

[0140] Embodiment 28 provides a process of any one of Embodiments 5-27, further comprising at least partially removing residual colorant from the continuous trough after applying the colorant directly to the elongate substrate in the trough, or after applying the colorant directly to the trough and transferring the colorant from the trough to the elongate substrate.

[0141] Embodiment 29 provides a process of any one of Embodiments 5-28, further comprising applying clear ink to the grooved transfer drum after applying the colorant directly to the elongate substrate in the trough, or after applying the colorant directly to the trough and transferring the colorant from the trough to the elongate substrate.

[0142] Embodiment 30 provides a process of any one of Embodiments 5-29, wherein applying the colorant directly to the elongate substrate in the trough, or after applying the colorant directly to the trough comprises selectively controlling the flow of at least one colorant through at least one selected from digital print-heads, electropneumatic valves, and electromagnetic valves.

[0143] Embodiment 31 provides a process of Embodiment 30, further comprising controlling the flow of at least two of the colorants through a digital print-head for application directly to the elongate substrate in the trough or for application directly to the trough.

[0144] Embodiment 32 provides a process of any one of Embodiments 16-31, wherein the additive is a colorant, further comprising positioning at least two of

the elongate substrates in separate troughs on the surface and applying the colorant to the at least two elongate substrates or applying the colorant to at least two of the troughs and transferring the colorant from the at least two troughs to the at least two elongate substrates.

[0145] Embodiment 33 provides a process of Embodiment 32, further comprising applying the colorant to the at least two elongate substrates in different patterns or transferring the colorant from the at least two troughs to the at least two elongate substrates in different patterns.

[0146] Embodiment 34 provides an elongate substrate colored by at a process of any one of Embodiments 1-33.

[0147] Embodiment 35 provides the elongate substrate of Embodiment 34, wherein the elongate substrate is a yarn.

[0148] Embodiment 36 provides a device for applying additive to an elongate substrate, an example device comprising: a grooved surface comprising at least one groove; and an additive dispenser to selectively apply additive directly onto the elongate substrate or onto a groove of the grooved surface.

[0149] Embodiment 37 provides an example device of Embodiment 36, further comprising a guide for holding the elongate substrate in the groove or in contact with additive in a groove of the grooved surface.

[0150] Embodiment 38 provides an example device of any one of Embodiments 36-37, wherein the additive dispenser is selected from the group consisting of a digital print-head, electropneumatic valve, and an electromagnetic valve.

[0151] Embodiment 39 provides an example device of any one of Embodiments 36-38, wherein the grooved surface is stationary.

[0152] Embodiment 40 provides an example device of any one of Embodiments 36-39, wherein the grooved surface is moving.

[0153] Embodiment 41 provides an example device of any one of Embodiments 36-40, wherein the elongate substrate is moving.

[0154] Embodiment 42 provides an example device of any one of Embodiments 36-41, wherein the grooved surface and the elongate substrate are stationary with respect to one another at a point of contact between the two.

[0155] Embodiment 43 provides an example device of any one of Embodiments 36-42, wherein the grooved surface and the elongate substrate are moving with respect to one another at a point of contact between the two.

[0156] Embodiment 44 provides an example device of any one of Embodiments 36-43, further comprising a sensor for measuring the linear velocity of the elongate substrate in relation to the grooved surface at a point of contact between the two.

[0157] Embodiment 45 provides an example device of any one of Embodiments 36-44, further comprising a sensor for measuring the linear velocity of the grooved surface.

[0158] Embodiment 46 provides an example device of any one of Embodiments 36-45, further comprising a control circuit for controlling the relative linear velocity of the yarn with respect to the grooved surface at a point of contact between the two.

[0159] Embodiment 47 provides an example device of any one of Embodiments 36-46, wherein the grooved surface is selected from a continuous surface and a discontinuous surface.

[0160] Embodiment 48 provides an example device of Embodiment 47, wherein the continuous surface comprises a drum or a belt.

[0161] Embodiment 49 provides an example device of any one of Embodiments 47-48, wherein the discontinuous surface comprises a plate.

[0162] Embodiment 50 provides an example device of any one of Embodiments 36-49, wherein the grooved surface is a drum comprising an outside diameter of 6 inches (152 mm) to 36 inches (914 mm).

[0163] Embodiment 51 provides an example device of any one of Embodiments 36-50, wherein the grooved surface is a drum comprising an outside diameter of 9 inches (229 mm) to 30 inches (762 mm).

[0164] Embodiment 52 provides an example device of any one of Embodiments 36-51, wherein the grooved surface is a drum comprising an outside diameter of 11 inches (279 mm) to 24 inches (610 mm).

[0165] Embodiment 53 provides an example device of any one of Embodiments 36-52, wherein the grooved surface comprises at least two of the grooves, wherein a groove to groove spacing of the grooved surface is 0.5 mm to 6 mm.

[0166] Embodiment 54 provides an example device of Embodiment 53, wherein the groove to groove spacing of the grooved surface is 1 mm to 4 mm.

[0167] Embodiment 55 provides an example device of any one of Embodiments 53-54, wherein the groove to groove spacing of the grooved surface is 1.5 mm to 3 mm.

[0168] Embodiment 56 provides an example device of any one of Embodiments 36-55, wherein the groove is a v-shaped groove.

[0169] Embodiment 57 provides an example device of any one of Embodiments 36-56, wherein the groove has a depth of 0.5 mm to 5 mm.

[0170] Embodiment 58 provides an example device of any one of Embodiments 36-57, wherein the groove has a depth of 1 mm to 3 mm.

[0171] Embodiment 59 provides an example device of any one of Embodiments 36-58, wherein the grooved surface and an outlet of the additive dispenser are spaced apart by a gap of 0.1 mm to 5 mm.

[0172] Embodiment 60 provides an example device of any one of Embodiments 36-59, wherein the grooved surface and an outlet of the additive dispenser are spaced apart by a gap of 0.5 mm and 3mm.

[0173] Embodiment 61 provides an example device of any one of Embodiments 36-60, wherein the additive is a colorant.

[0174] Embodiment 62 provides an example device of any one of Embodiments 36-61, wherein the additive comprises a chemical treatment other than colorant.

[0175] Embodiment 63 provides a process, elongate substrate, or device of any one or any combination of Embodiments 1-62 optionally configured such that all elements or options recited are available to use or select from.

[0176] Embodiment 64 provides a process of any of the foregoing Embodiments wherein the elongate substrate is not torqued or twisted during the application of the additive, agent or colorant to the elongate substrate. In a further Embodiment 65, during the process of coloration, no additional twist or torque is intentionally added.

[0177] Embodiment 65 provides a process to at least partially overcome the problem of requiring a non-aqueous ink with an externally applied electrostatic charge by operating with an aqueous ink and no externally applied electrostatic charge.

CLAIMS

What is claimed is:

1. A process for applying an agent to an elongate substrate, a process comprising:
 - contacting the elongate substrate with the trough; and
 - transferring the agent to the elongate substrate, the transferring comprising
 - applying the agent directly to the elongate substrate in the trough,
 - applying the agent directly to the trough and transferring the agent from the trough to the elongate substrate, or
 - a combination thereof
 - wherein applying agent directly to the elongate substrate in the trough, or applying the agent directly to the trough, comprises selectively controlling the flow of the agent through at least one selected from a digital print-head, electropneumatic valve, and an electromagnetic valve.
2. A process of claim 1, wherein a process comprises:
 - applying the agent directly to the trough and transferring the agent from the trough to the elongate substrate.
3. A process of claim 1, wherein a process comprises applying the agent directly to the elongate substrate in the trough.
4. A process of claim 1, wherein the agent comprises a colorant, clear ink, a wetting agent, a stain-resist chemical, a water-repellent chemical, or a combination thereof.
5. A process of claim 4, wherein the agent comprises a colorant.
6. A process of claim 1, wherein the elongate substrate comprises a yarn.

7. A process of claim 1, wherein the trough is in a surface that comprises more than one trough, and the surface is selected from a cylindrical surface, an elliptical surface, a cylindrical section and an elliptical section.
8. A process of claim 1, wherein the trough has a width of 0.1 mm to 5 mm.
9. A process of claim 1, further comprising moving the trough along its longitudinal direction and moving the elongate substrate in the same direction of trough movement or counter to the direction of trough movement.
10. A process of claim 1, wherein the trough comprises a groove, wherein a grooved drum or belt comprises the trough.
11. A process of claim 7, wherein the agent is a colorant, further comprising positioning at least two of the elongate substrates in separate troughs on the surface and applying the colorant to the at least two elongate substrates or applying the colorant to at least two of the troughs and transferring the colorant from the at least two troughs to the at least two elongate substrates.
12. The process of any one preceding claim wherein the elongate substrate is a bulked yarn.
13. An elongate substrate colored by at a process of claim 1.
14. A device for applying additive to an elongate substrate, the device comprising:
 - a surface comprising at least one groove; and
 - an additive dispenser to selectively apply additive directly onto the elongate substrate or onto a groove of the surface.

15. The device of claim 14, further comprising a guide for holding the elongate substrate in the groove or in contact with additive in a groove of the surface.

16. The device of claim 14, wherein the additive dispenser includes a digital print-head, an electropneumatic valve, or an electromagnetic valve.

17. The device of claim 14, wherein the surface is a drum having an outside diameter of 6 inches (152 mm) to 36 inches (914 mm).

18. The device of claim 14, wherein the surface includes at least two grooves spaced apart by 0.5 mm to 6 mm.

19. The device of claim 14, wherein the groove is a v-shaped groove or a u-shaped groove.

20. The device of claim 14, wherein the surface and an outlet of the additive dispenser are spaced apart by a gap of 0.1 mm to 5 mm.

21. The device of any one of claims 14-20 wherein the additive dispenser is a digital printhead having a plurality of nozzles in at least one row.

22. A process for applying an agent to a bulked discontinuous elongate substrate, a process comprising:

contacting the bulked discontinuous elongate substrate with the trough; and

transferring the agent to the bulked discontinuous elongate substrate, the

transferring comprising

applying the agent directly to the bulked discontinuous elongate

substrate in the trough,

applying the agent directly to the trough and transferring the agent

from the trough to the bulked discontinuous elongate substrate, or

a combination thereof

wherein applying agent directly to the bulked discontinuous elongate substrate in the trough, or applying the agent directly to the trough, comprises selectively controlling the flow of the agent through at least one selected from a digital print-head, electropneumatic valve, and an electromagnetic valve.

23. A process of claim 22, wherein a process comprises:
applying the agent directly to the trough and transferring the agent from the trough to the elongate substrate.

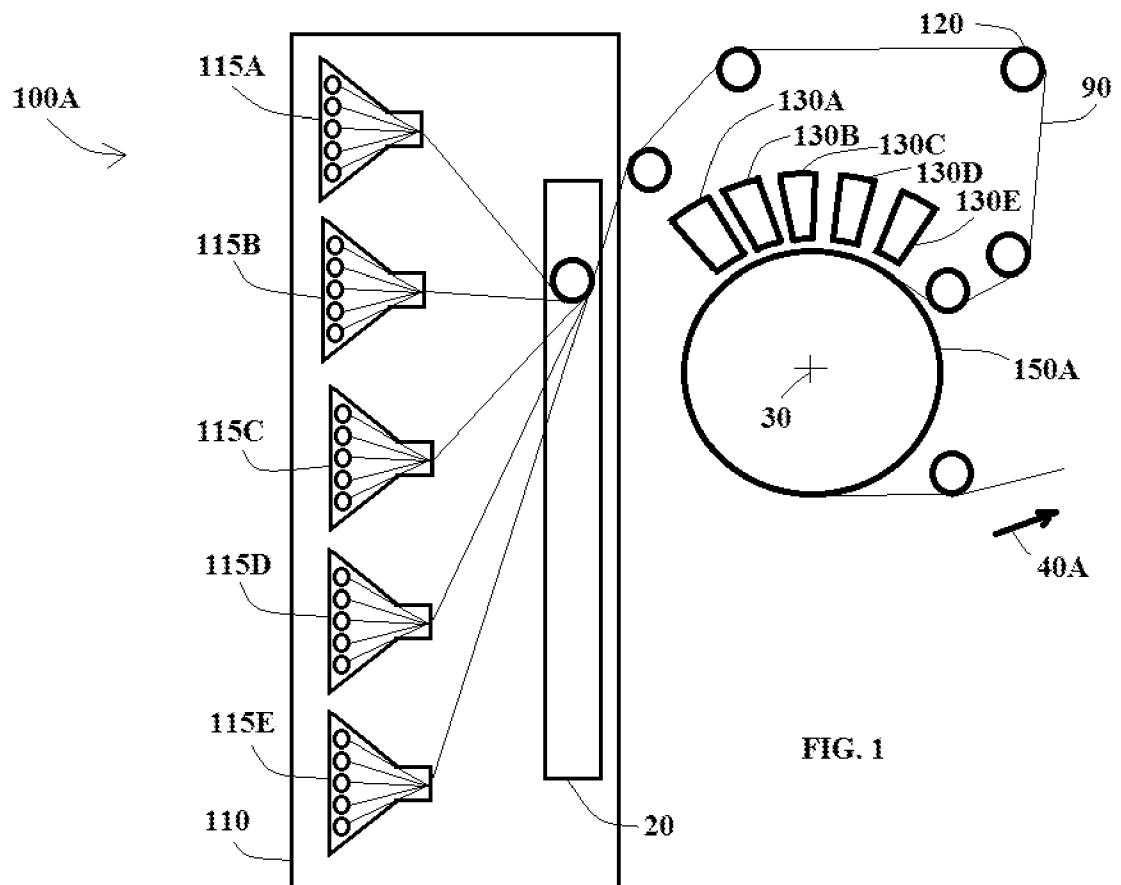
24. A process of claim 22, wherein a process comprises applying the agent directly to the elongate substrate in the trough.

25. A process of claim 22, wherein the agent comprises a colorant, clear ink, a wetting agent, a stain-resist chemical, a water-repellent chemical, or a combination thereof.

26. The process of any one preceding claim wherein no external electrostatic charge is applied to an elongate substrate.

27. The process of any one preceding claim wherein the agent is aqueous.

28. The process of any one preceding claim further comprising transferring the agent to the trough through a plurality of nozzles in a multinozzle printhead.



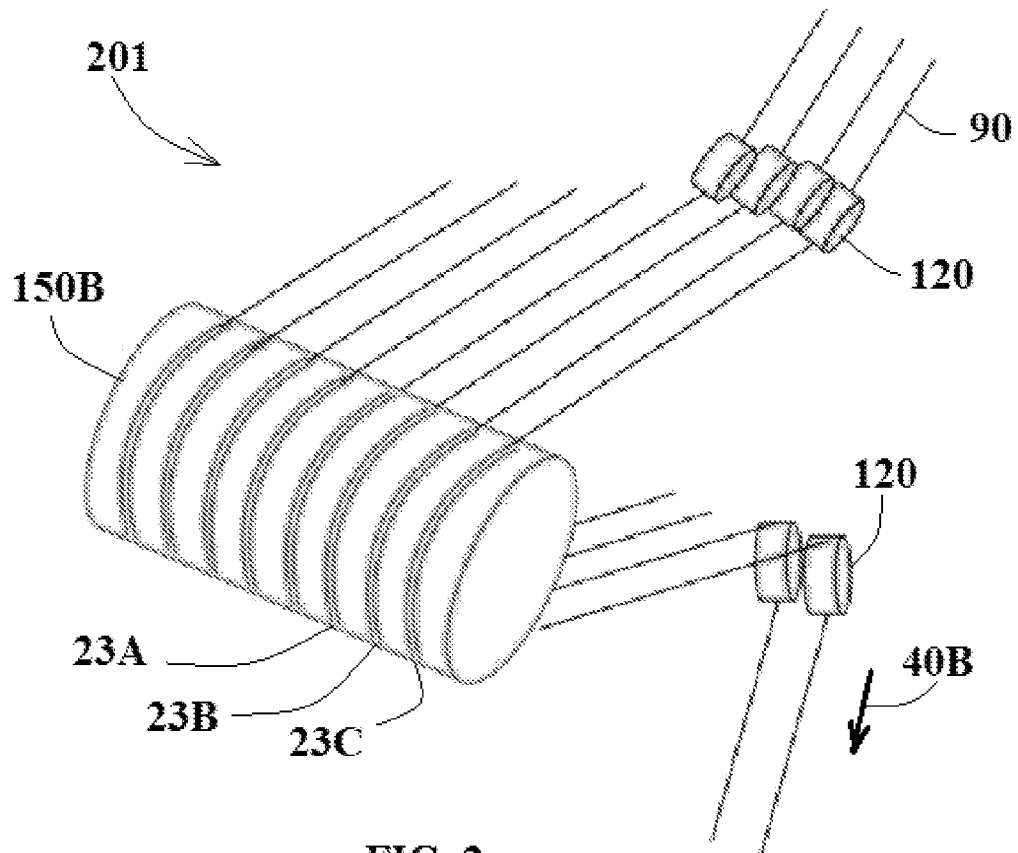


FIG. 2

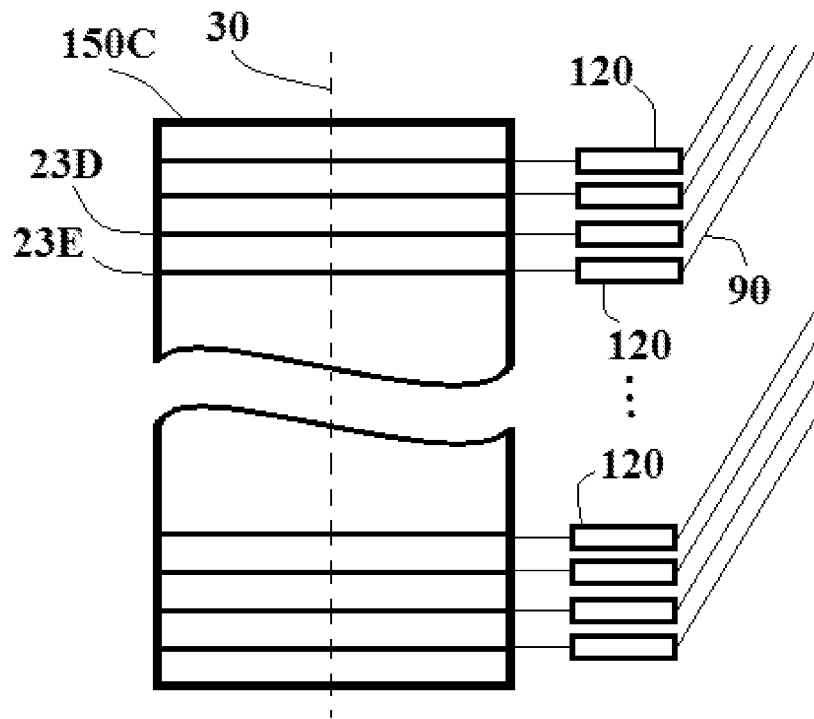


FIG. 3A

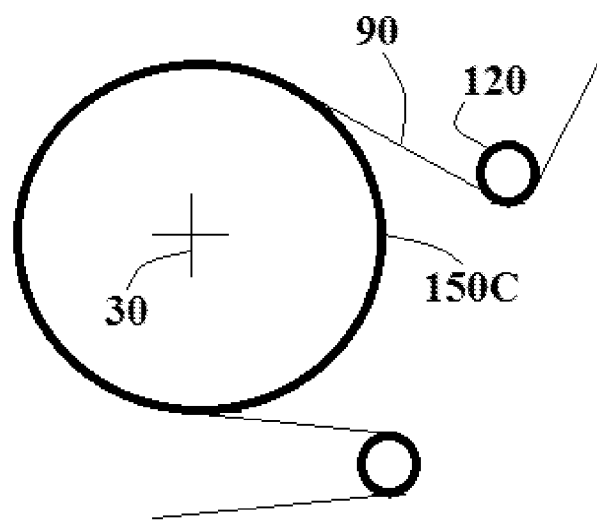
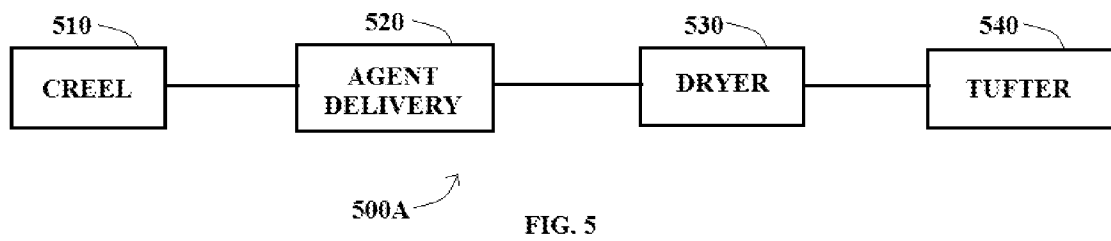
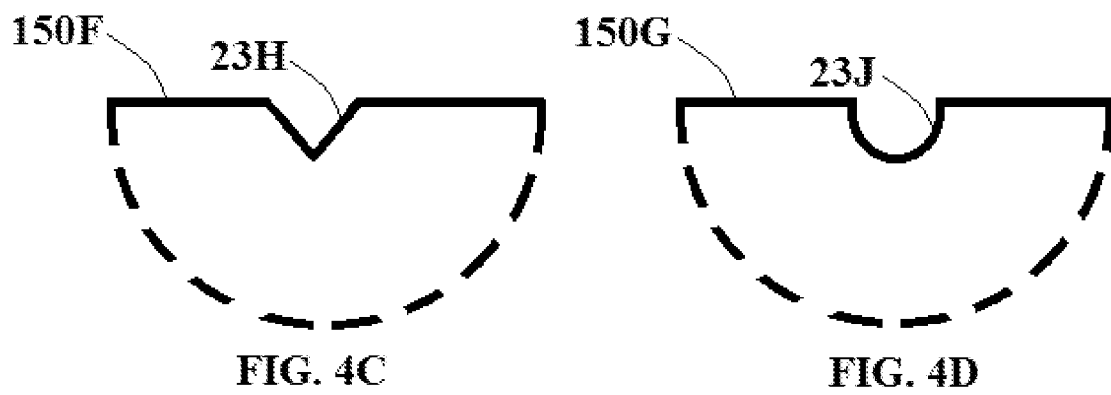
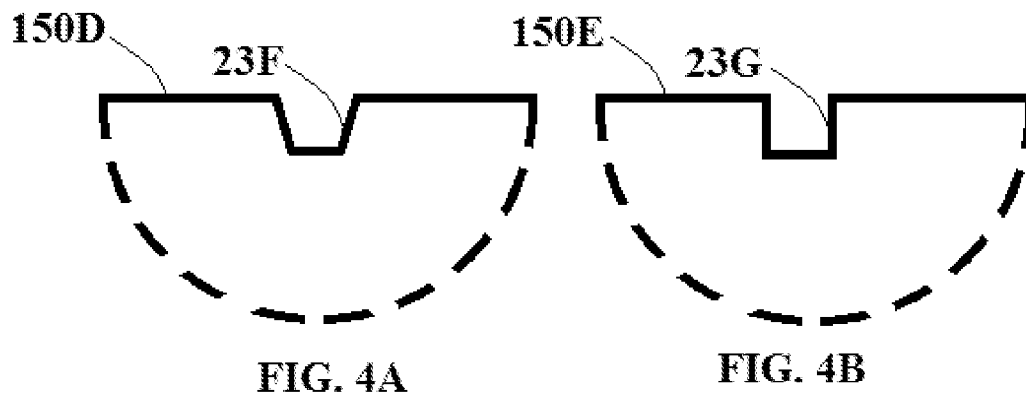


FIG. 3B



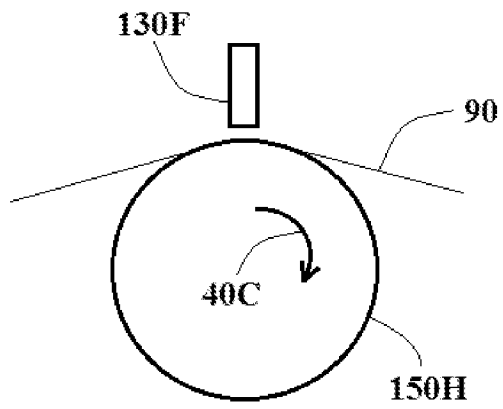


FIG. 6A

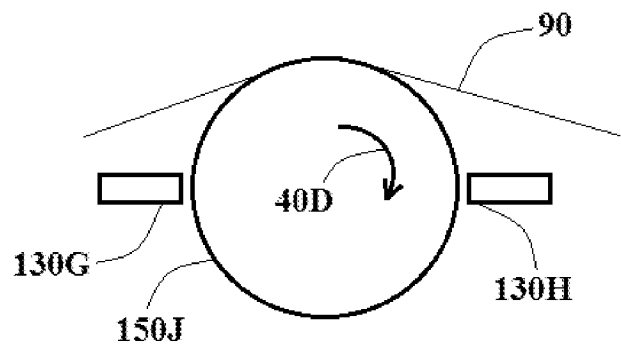


FIG. 6B

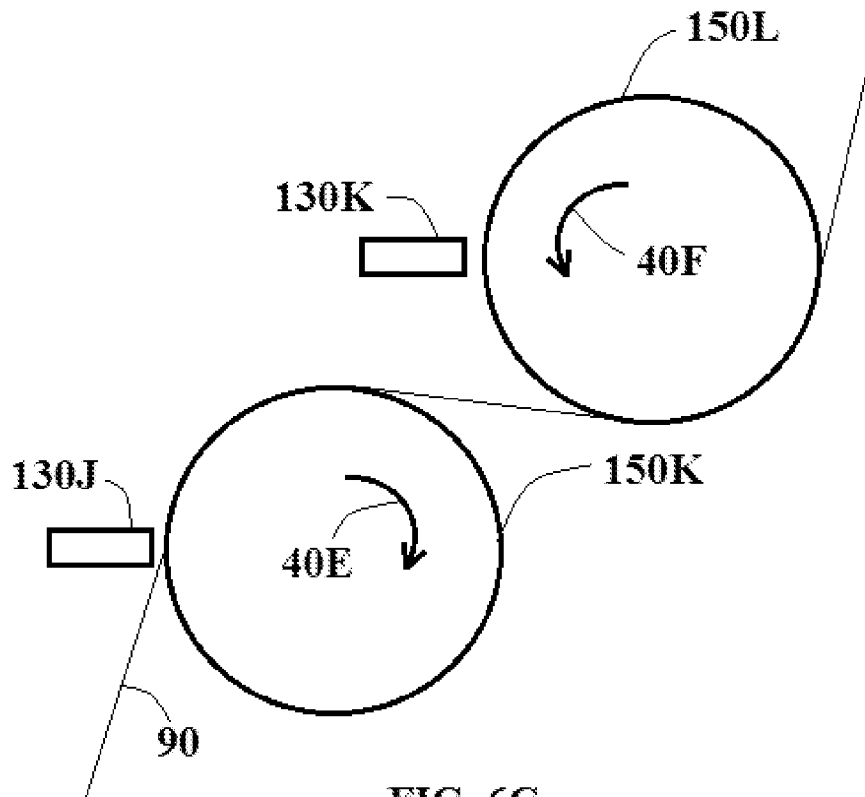


FIG. 6C

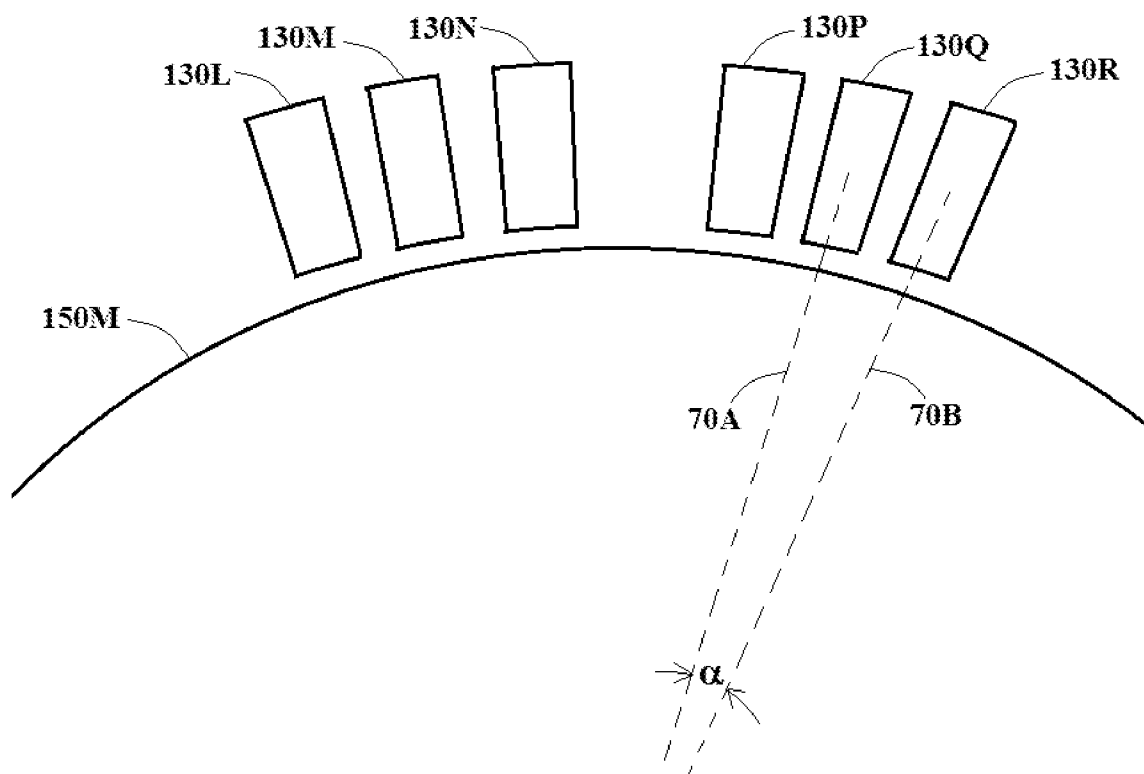


FIG. 7

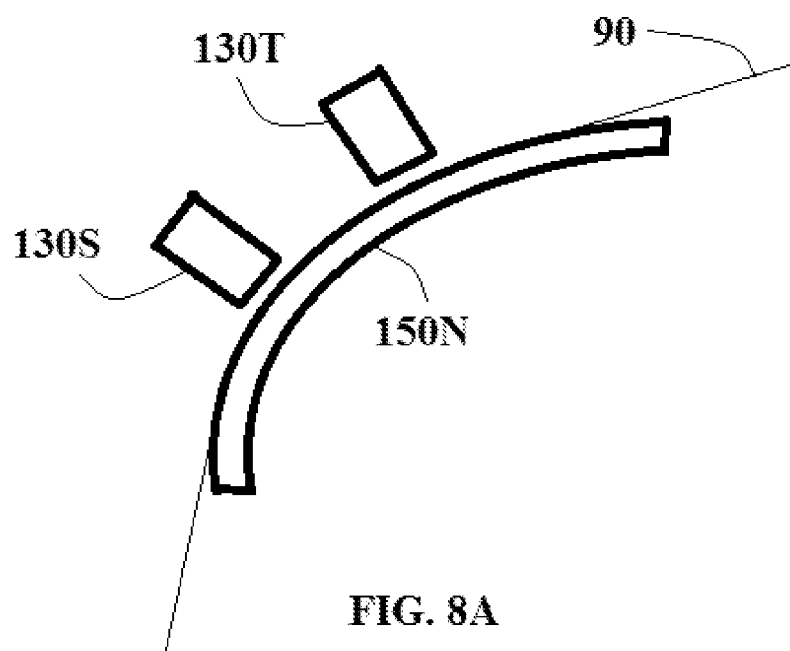


FIG. 8A

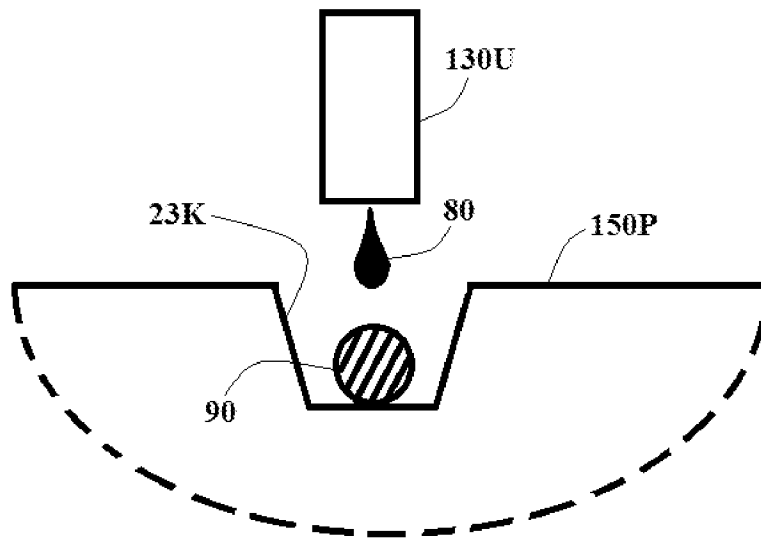


FIG. 8B

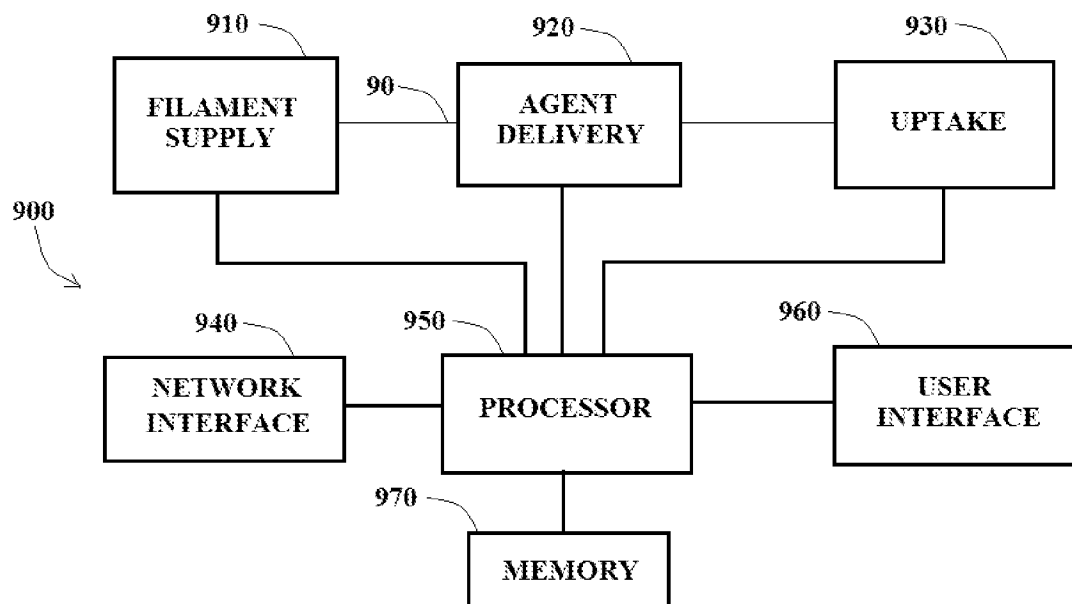


FIG. 9

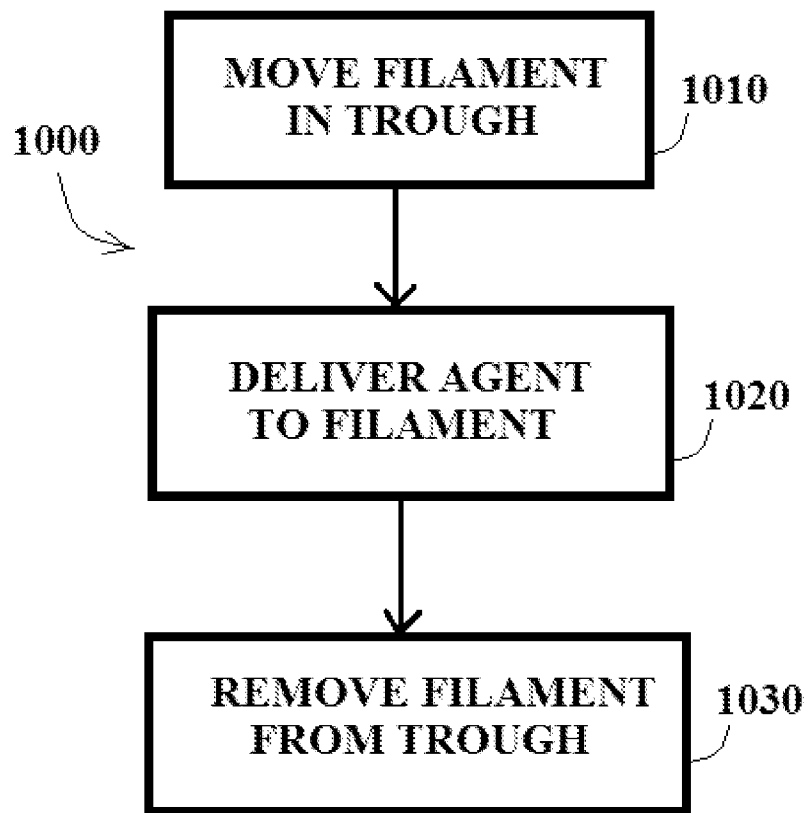


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2019/060057

A. CLASSIFICATION OF SUBJECT MATTER

INV. D06B11/00 D06P5/30 D06B1/14 D06P1/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B65D B05B D05C D06B D06Q D06P B41J A47G D03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/135931 A1 (SHAW HENRY [FR]) 24 July 2003 (2003-07-24)	1,13,22, 24-28
Y	paragraphs [0001], [0024], [0025], [0029]; claims 1,5; figures 1,2 fig. 5, par. [0033], last sentence paragraph [0035]; figure 7 paragraph [0038]; figure 10 -----	1,7,11, 14,22-28
Y	US 3 253 437 A (MINSHULL ROBERT G) 31 May 1966 (1966-05-31) column 2, lines 38-43; figures 1,3 -----	1,7,11, 14,22-28
X	WO 2008/011645 A1 (PETER ZIMMER KEG [AT]; ZIMMER PETER [AT]) 31 January 2008 (2008-01-31)	1,3-21
Y	page 5, lines 8-28; claim 1; figures 1-4,19 ----- -/--	7,11



Further documents are listed in the continuation of Box C.



See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

26 February 2020

Date of mailing of the international search report

05/03/2020

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Authorized officer

Uhlig, Robert

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2019/060057

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	column 2, lines 57-68; claim 1; figures 1,2,6-8 column 4, lines 11-19,36-41 -----	7,11,23
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Information on patent family members

International application No

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