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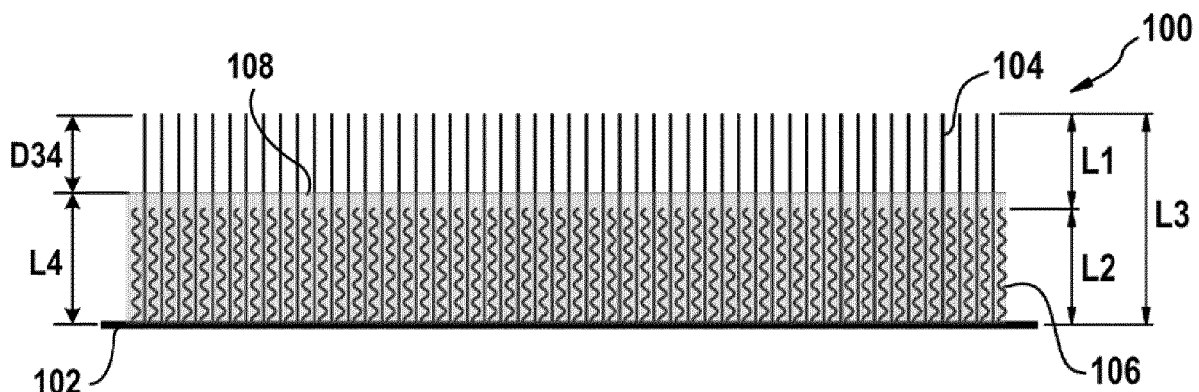
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(54) **TUFTED ARTIFICIAL TURF**

(57) The invention relates to a tufted artificial turf (100) comprising: an artificial turf carpet comprising a carrier (102), indicator yarn fibers (106) and face yarn fibers (104) and an artificial turf infill (108) distributed between the indicator yarn fibers (106) and the face yarn fibers (104), wherein the face yarn fibers and the indicator yarn fibers being tufted into the carrier such, that the face yarn fibers (104) protrude from the carrier (102) with a face yarn fiber height (L3) and the indicator yarn fibers (106) protrude from the carrier with an indicator yarn

height (L2), wherein the face yarn fiber height (L3) being larger than the indicator yarn fiber height (L2), wherein the artificial turf infill (108) has an installation height (L4) above the carrier (102), wherein the installation height (L4) is greater than the indicator yarn fiber height (L2); and wherein the indicator yarn fibers (106) have a first optically visible contrast relative to the face yarn fibers (104) and wherein the indicator yarn fibers (106) have a second optically visible contrast relative to the artificial turf infill (108).

Fig. 1



Description**Field of the invention**

[0001] The invention relates to the field of synthetic turfs and more particularly to a tufted artificial turf and a method of maintaining the tufted artificial turf.

Background and related art

[0002] Artificial turfs are a surface generally used to replace natural grass surfaces and comprise rows of fibers that extend vertically from a backing layer. The distance the rows of fiber extend from the backing layer may be referred to as the pile height. The structure of the artificial turf is designed such that the artificial turf has an appearance which resembles grass. An infill layer of particulate material is often interspersed between the fibers extending from the backing layer. Typically, artificial turf is used as a surface for sports such as soccer, American football, rugby, tennis, golf, hockey or for other playing fields or exercise fields. Furthermore, artificial turf is frequently used for landscaping applications. An advantage of using artificial turf is that it eliminates the need to care for a grass playing or landscaping surface, like regular mowing, scarifying, fertilizing, and irrigating.

[0003] Some artificial turf types are known which comprise a combination of fibers of two different lengths. For example, US patent application US 6,299,959 B1 describes synthetic grass having both surface forming non-textured fibers and textured thatch zone forming fibers to add resilience and to lock in rubber granules which are distributed more densely near the base of the fibers. In one embodiment of this arrangement, the covering rubber like particles are used to stabilize the synthetic surface fibers in their upright position.

[0004] Generally, the fibers of artificial turf known in the prior art is formed by tufting the fibers through one or more carrier layers. The tufting is generally done using a conventional tufting machine. The fibers are stitched into the carrier layer, leaving loops, which form the turf pile. These piles may be a loop pile and/or a cut pile. Once the fibers are tufted in place through the carrier layer, the carrier layer may be further coated on its back with a backing layer, which is generally a urethane or latex coating, to help adhere the stitched fibers to the carrier and to provide dimensional stability.

[0005] Even though the artificial turf known from the art are constantly further developed, repeated use or weather influences, such as rain or wind, can cause the infill material (artificial turf infill) to be discharged or to become unevenly distributed resulting in the formation of mounds or holes. However, these holes and mounds can be disadvantageous for the practice of ball sports, as they cause an unpredictable bounce or deceleration of the ball. In addition, these holes and elevations can be dangerous for the users, as they could get caught in them or cause them to stumble, which might lead to in-

juries.

Summary

[0006] The invention provides for tufted artificial turf, a method, an artificial turf maintenance robot system, and an artificial turf system in the independent claims. Embodiments are given in the dependent claims.

[0007] For many applications of artificial turf, an artificial turf carpet is used with artificial turf infill. The artificial turf carpet comprises yarn fibers which extend above a carrier to form a pile. The artificial turf infill is a granulate and/or particulate infill which is distributed between the yarn fibers. Having the proper amount of artificial turf infill between the fibers affects how the surface behaves when used for sports. This is particularly true if there is too little artificial turf infill in some locations. It is therefore of interest to maintain a proper amount of artificial turf infill.

[0008] Embodiments may provide for a means of more easily maintaining the proper amounts of artificial turf infill. Artificial turf infill is provided which has yarn fibers of two lengths. The longer artificial turf fibers is referred to as the face yarn fibers and the shorter artificial turf fibers are referred to as the indicator yarn fibers. The indicator yarn fibers may have a color which is chosen such that it is visible against both the face yarn fibers and the artificial turf infill. The length of the indicator yarn fibers is chosen such that it is just below a desired depth (a predetermined depth) of artificial turf infill. If there is too little artificial turf infill in a region, then the indicator yarn fibers are visible. The artificial turf infill can then be distributed (either redistributed or more infill provided) so that the indicator yarn fibers are no longer visible. In this way it can be easily assured that a minimum depth of artificial turf infill is provided. The use of the indicator yarn fibers enables maintenance personnel to visually scan a field and tell very quickly where the artificial turf needs to be distributed. This process can also be automated by using cameras to detect visible indicator yarn and then control a robot to distribute the artificial turf infill.

[0009] Some embodiments may have the benefit that the tufted artificial turf is easier to maintain artificial turf and methods for maintaining the same.

[0010] In one aspect, the invention relates to an tufted artificial turf comprising an artificial turf carpet comprising a carrier, indicator yarn fibers and face yarn fibers, and an artificial turf infill distributed between the indicator yarn fibers and the face yarn fibers. The face yarn fibers and the indicator yarn fibers are tufted into the carrier such, that the face yarn fibers protrude vertically from the carrier with a face yarn fiber height and the indicator yarn fibers protrude vertically from the carrier with an indicator yarn height, wherein the face yarn fiber height is larger than the indicator yarn fiber height. Further, the artificial turf infill has an installation height above the carrier, wherein the installation height is greater or equal than the indicator yarn fiber height. In addition, the indicator yarn fibers have an first optically visible contrast relative to the face

yarn fibers and wherein the indicator yarn fibers have a second optically visible contrast relative to the artificial turf infill.

[0011] The yarns of the indicator yarn fibers and the face yarn fibers may be monofilament yarns that are tufted and anchored into the carrier as loops, which may then be cut, which then results in two fibers, also so-called ribbons, for each stitched or tufted loop of yarn. An "indicator yarn" as used herein is yarn used with a different optically visible contrast compared to either the face yarn or the artificial turf infill. A "face yarn" (or "pile yarn") as used herein is the yarn that protrudes vertically from the carrier of the artificial turf farther than any other type of yarn contained in the artificial turf, if any, thereby determining the pile height of the artificial turf.

[0012] It is feasible that multiple, usually between 2 and 4 yarns are tufted into the same tuft by the same needle, therefore resulting in 4, 6 or 8 fibers per tuft, which extend upwardly from the carrier and which may represent blades of grass. It is possible that either only indicator yarn fibers or only face yarn fibers or a combination of indicator yarn fibers and face yarn fibers are arranged per tuft. It is further feasible that the indicator yarn fibers and the face yarn fibers are straight (non-texturized) fibers or texturized fibers.

[0013] The term "tufting" as used herein is a sub-process in the manufacturing of artificial turf that comprises pressing (e.g. by using pneumatic force) a U-shaped piece of yarn through a carrier, e.g. a carrier mesh or other form of carrier structure. The carrier of the artificial turf carpet may comprise a single layer of material or multiple layer of material, and the individual layers may be either woven or nonwoven material.

[0014] The height of the artificial turf fibers (face yarn fibers and indicator yarn fibers) may be altered solely by cutting the respective yarn shorter or leaving it longer. The height of the artificial turf fibers may be also altered by stretching the fibers while being cut and/or subjecting the fibers to a contraction inducing condition that modulates the height of face yarn fibers and indicator yarn fibers differently such that an indicator yarn layer with a homogeneous fiber length and a face yarn layer with a different homogeneous fiber length is generated. It is envisaged that the height of the face yarn layer, respectively the height of the face yarn fibers, is larger than the height of the indicator yarn layer, respectively the height of the indicator yarn fibers.

[0015] The indicator yarn fibers and face yarn fibers protrude in the same direction, preferably each with a predefined shared fiber height. It is envisioned that face yarn fibers protrude from the carrier with a face yarn fiber height and the indicator yarn fibers protrude from the carrier with an indicator yarn height, wherein the face yarn fiber height is larger than the indicator yarn fiber height. It may be further advantageous that all face yarn fibers have basically the same length (measured from the point where the fiber is integrated in the carrier and the end of the fiber protruding from the carrier). Preferably, the

height deviations of the face yarn fibers is below 6% of the fiber length, preferably below 2.5% of the fiber length. It may be further advantageous that all indicator yarn fibers have basically the same length (measured from the point where the fiber is integrated in the carrier and the end of the fiber protruding from the carrier). Preferably, the height deviations of the indicator yarn fibers is below 6% of the fiber length, preferably below 2.5% of the fiber length.

[0016] An artificial turf infill is distributed or interspersed between the indicator yarn fibers and the face yarn fibers on the carrier for filling up the space between the fibers, for ballast and cushion. The infill may comprise sand, rubber granulate, elastic granules or a mixture thereof. It is within the scope of the invention that the infill installation height above the carrier is greater than the indicator yarn fiber height. Thus, if the infill is installed correctly, no indicator yarn fibers are optically visible, since it belongs to the invention that the indicator yarn fibers have a first optically visible contrast relative to the face yarn fibers and a second optically visible contrast relative to the artificial turf infill.

[0017] The first optically visible contrast and the second optically visible contrast may be the same contrast. Further, the optically visible contrast might be any contrast distinguishable by the human eye or by optical means. For example, the optically visible contrast may be a color contrast, which may be distinguishable by the human eye. Hence, if the face yarn fibers and the infill have for example a green color and the indicator yarn fibers have a blue color, the indicator yarn fibers are not optically visible, if the infill is installed with the correct installation height. Optically visible are in this case only the face yarn fibers, since their heights are larger than the height of the indicator yarn fibers, and the infill material, since the installation height of the infill is greater than the indicator yarn fiber height. However, in case that the infill is not correctly installed or that the layer of infill material has been disturbed by a user or rough weather, the - in the example blue - indicator yarn fibers are optically visible in places where the infill has been moved. It is therefore easy for the user to determine which areas should be prepared or maintained.

[0018] In one embodiment of the invention, the face yarn fibers have a optically visible contrast relative to the artificial turf infill.

[0019] This might be further advantageous for distinguishing the optically visible contrast between the indicator yarn fibers and the artificial turf infill, in particular if the contrast difference between the infill and the indicator yarn fibers is bigger than the contrast difference between the face yarn fibers and the infill.

[0020] In another embodiment of the invention, the indicator yarn fibers are texturized or straight fibers and the face yarn fibers are straight fibers.

[0021] To delay and reduce texture reversion of a textured fiber, it is further envisaged for another embodiment of the invention that the texturized fibers are produced

from stretched and textured monofilament yarn comprising a polymer mixture, wherein the polymer mixture is at least a three-phase system, wherein the polymer mixture comprises a first polymer, a second polymer, and a compatibilizer, wherein the first polymer and the second polymer are immiscible, wherein the first polymer forms polymer beads surrounded by the compatibilizer within the second polymer.

[0022] Hereby it may be advantageous that the first polymer comprises polyamide, wherein the second polymer comprises polyethylene.

[0023] Further, it may be useful that the compatibilizer comprises any one of the following: a maleic acid grafted on polyethylene or polyamide; a maleic anhydride grafted on free radical initiated graft copolymer of polyethylene, SEBS, EVA, EPD, or polypropylene with an unsaturated acid or its anhydride such as maleic acid, glycidyl methacrylate, ricinoleoxazoline maleinate; a graft copolymer of SEBS with glycidyl methacrylate, a graft copolymer of EVA with mercaptoacetic acid and maleic anhydride; a graft copolymer of EPDM with maleic anhydride; a graft copolymer of polypropylene with maleic anhydride; a polyolefin-graft-polyamidepolyethylene or polyamide; and a polyacrylic acid type compatibilizer.

[0024] Since the face yarn fibers are straight (non-texturized) fibers they may resemble grass blades better than texturized fibers. The compared to the face yarn fibers shorter indicator fibers add resilience and lock in infill granules which are distributed more densely near the base of the fibers. To add further reliance, it may be advantageous that the indicator yarn fibers are texturized. A "texturized" fiber as used herein is a fiber that has a molecular memory of a textured state, wherein a textured state can be, for example, a curled, crumpled and/or wrinkled state. The primarily formed texturized fiber is tufted into a turf surface and forms the uncoated carpet (greige good). In a further step the final carpet is formed from the greige good by coating of the greige good with a so-called secondary backing e.g. a two-component polyurethane coating, a water based styrene butadiene latex coating, a hotmelt coating or the like. In all cases the carpet fibers are exposed to heat during the coating process and show a shrinking and a post texturization (a further increase of the curling/ wrinkled state). It is envisaged that the texturized fibers are texturized such, that the fibers extending from the carrier have a texturization degree, also referred to as bulkiness, between 7% and 30 %, preferable between 8% and 22% and most preferred between 13% and 17%. The relative length difference of the texturized yarn prior and after the heat exposure is defined as texturization degree or bulkiness. The desired bulkiness can be obtained with methods known in the art. For example, one method to obtain the desired bulkiness is to expose the texturized yarn for five minutes to 90°C (which simulates the post texturization) and to measure the shrinkage of the texturized yarn under weight. In a further beneficial aspect, the rigidity of the face yarn fibers is increased by the texturized shorter

indicator yarn fibers even if no infill is present or if the height of the infill layer is lower or much lower than the height of the face yarn fibers. This may allow providing an artificial turf that is particularly robust against wear and tear.

[0025] Hence, it might be in particular advantageous that the indicator yarn fibers are texturized.

[0026] In another embodiment of the invention, the height difference between the face yarn fiber height and the installation height is equal or greater than 1 mm.

[0027] This height difference is in particular important for the bouncing and braking or deceleration behavior of balls on artificial turf and is therefore dependent on the type of sport. For example, it is advantageous that the free pile height, meaning the height difference between the face yarn fiber height and the installation height of the infill (infill fill height) is for an artificial football turf between 18 mm and 22 mm. For a sand dressed artificial hockey turf, which is a hockey turf which is e.g. filled with sand, it is advantageous that the height difference (free pile height) is between 5 mm and 14 mm. For paddle tennis or tennis, the height difference may preferably be between 1 mm and 5 mm.

[0028] In another embodiment of the invention, the carrier comprises tufts, comprising at least two indicator yarn fibers, which are integrated into the carrier in the form of first rows and wherein the carrier further comprises tufts, comprising at least two face yarn fibers, which are integrated into the carrier in the form of second rows, wherein the first rows and second rows alternate and wherein the first rows and second rows are parallel to each other.

[0029] Alternatively, in another embodiment of the invention, the carrier comprises tufts, comprising in the same tuft at least two indicator yarn fibers and at least two face yarn fibers. These tuft can be integrated into the carrier in the form of third rows, whereby the third rows are parallel to each other.

[0030] Alternatively, in another embodiment of the invention, the carrier comprises first tufts, comprising at least two indicator yarn fibers, and second tufts, comprising at least two face yarn fibers, wherein the first tufts and the second tufts alternate and wherein the first and second tufts are integrated into the carrier in the form of a fourth row. It goes without saying that it is also conceivable that the arrangement of the first and second tufts could also be first tuft - first tuft - second tuft - first tuft - first tuft - second tuft or second tuft - second tuft - first tuft - second tuft - second tuft - first tuft. Further, it may be advantageous that the rows are arranged such that the first tufts are arranged beside the second tufts.

[0031] For all three alternatives it is further feasible that the rows are straight lines and/or zig-zag lines.

[0032] It is further feasible that first rows, second rows, third rows and fourth rows may be alternating in this order or in any other.

[0033] In a further aspect, the invention relates to a method for maintaining a tufted artificial turf as described above. The method comprises the steps of

- i. inspecting the tufted artificial turf to identify a region, where the optically visible contrast of the indicator yarn fibers relative to the infill is optically detectable and
- ii. redistributing and/or providing additional infill in order to cover the indicator yarn fibers such that the contrast disappears.

[0034] Before step i. the method may further comprise the step of filling up the tufted artificial turf (100) with an infill to the desired installation height, which is, as explained above dependent on the sport which is played on the artificial turf.

[0035] In one embodiment of the method, the step of inspecting is performed by visual inspection.

[0036] In another embodiment of the method, the step of inspecting is performed by means with an optical sensor. Hereby, it may be feasible that the means with an optical sensor are arranged within a maintenance robot.

[0037] In another aspect the invention provides for an artificial turf maintenance robot system. The artificial turf maintenance robot system may be used for the maintenance of a tufted artificial turf filled with an artificial turf infill. The artificial turf maintenance robot system comprises a self-driving robot configured for distributing artificial turf infill within the tufted artificial turf. As used herein the term 'distributing' may encompass moving artificial turf infill from one portion of the tufted artificial turf and/or it may include adding additional or more artificial turf infill to the tufted artificial turf. The artificial turf maintenance robot system further comprises a processor for controlling the artificial turf maintenance robot system. As used herein a processor may encompass one or more processors and may also encompass a distributed computing system. For example there may be one or more processors located on the self-driving robot and there may be also additionally processors at a different location which is used to control the self-driving robot.

[0038] The artificial turf maintenance robot system further comprises a memory containing machine-executable instructions for execution by the processor. Execution of the machine-executable instructions causes the processor to receive optical data descriptive of a location of indicator yarn fibers. Execution of the machine-executable instructions further cause the processor to control the self-driving robot using the optical data to distribute artificial turf infill to optically obscure the indicator yarn fibers. The indicator yarn fibers are fibers which can be detected using an optical detection system such as a camera. The optical data indicates the locations where indicator yarn fibers are visible. The optical data is then used to generate for example control instructions which are used to control the self-driving robot to optically obscure the indicator yarn fibers. The obscuring of the indicator yarn fibers may be performed by distributing the artificial turf infill to cover them. This could involve either moving artificial turf infill and distributing it more evenly to cover exposed indicator yarn fibers or it may also include the

dispensing or adding of artificial turf infill.

[0039] The optical data can be used to automatically differentiate between the indicator yarn fibers and the face yarn fibers. Color data can be used to determine a difference in color space. This can be achieved by measuring the difference in color space and determining if the difference between two colors is above a predetermined threshold. For example, to achieve an indicator function of the indicator yarn fibers, the color of one or several of the texturized thatch yarns may have a significant enough color distance to the infill on one side, which may be used to indicate a lack of coverage of the indicator yarn fibers by the infill.

[0040] In a specific example, the color distance can be e.g. expressed in terms of the Cie-L*a*b* color space. The color in the Cie Lab color space is expressed in 3 numerical values: L for the lightness, a* for the green-red color components and b* for the blue-yellow color components (color axis) of the respective. An example of the color distance is e.g. the distance between a face yarn in a standard turf olive and indicator yarn in an intensive blue tone. The measured color difference is $\Delta L = +8,84$, $\Delta a = -6,98$, $\Delta b = +50,33$, $\Delta E = +51,57$. A visible difference is achieved when ΔE exceeds a minimum value of 0.5. With lesser indicator fiber (e.g. only 1 fiber per bundle) the color distance should typically exceed a ΔE of 1.0. This technique can also be applied to other color spaces such as RGB density.

[0041] In another embodiment the self-driving robot comprises a brush configured for distributing the artificial turf infill. The brush may for example be a static brush which is moved over the surface by movement of the self-driving robot. The brush may also be powered or rotatable. For example the brush may be a cylindrical brush that is rotated and used to move the artificial turf infill or distribute it more evenly. In some examples the brush may also have a mechanism for actuating or moving the brush and also moving it to a different height relative to the artificial turf carpet used in the tufted artificial turf. This embodiment may be beneficial because it may provide for a means of automatically maintaining a tufted artificial turf with an optimum amount of artificial turf infill.

[0042] In another embodiment the self-driving robot comprises at least two drive wheels configured for propelling the self-driving robot.

[0043] In another embodiment the self-driving robot comprises a hopper configured for storing the artificial turf infill. A hopper as used herein encompasses a storage region or storage container for the artificial turf infill. The self-driving robot further comprises a controllable dispenser for dispensing the artificial turf infill from the hopper. For example the controllable dispenser may be an opening in the bottom of the hopper which is actuated. Execution of the machine-executable instructions further cause the processor to control the controllable dispenser to dispense artificial turf infill to optically obscure the indicator yarn fibers. This embodiment may be beneficial

because it may be used to replace lost artificial turf infill or supplement the artificial turf infill presently on a tufted artificial turf.

[0044] In another embodiment the artificial turf maintenance robot system further comprises an optical detection system configured for acquiring the optical data. Execution of the machine-executable instructions further causes the processor to control the optical detection system to acquire the optical data. In one example the optical detection system is a camera. This may be beneficial because it may provide for an easy means of detecting the location of indicator yarn fibers.

[0045] The optical detection system may be implemented in several different ways. In one example the optical detection system is a color camera. The color of the indicator yarn fibers may be used to detect its location. In other examples the optical detection system could be used to identify the location of the indicator yarn fibers by using filters to control the frequency range of light that reaches the optical detection system.

[0046] As used herein optical data may encompass raw data from an optical detection system or a camera which indicates the location of the indicator yarn fibers. In some instances the optical data is image data that has been processed to locate the position of indicator yarn fibers. This for example may be performed by taking a color image and searching the image for regions with a particular color range. In some instances the generation of the optical data may also include not only looking for regions of a certain color but looking for certain concentrations of this color. For example if only a small number of indicator fibers are visible in an image the optical data could decide not to indicate this region as needing to be filled.

[0047] In another embodiment the artificial turf maintenance robot system comprises a drone. The drone comprises a drone camera for at least partially imaging the tufted artificial turf. The optical detection system comprises the drone camera. This embodiment may be beneficial because the drone may be able to hover above an artificial turf such as a sports field and survey the field and look for regions that need to have the artificial turf infill either redistributed or added to the field. The artificial turf maintenance robot system may also comprise appropriate radio communication to enable acquired images to reach the processor.

[0048] In another embodiment the optical detection system comprises one or more fixed cameras configured for at least partially imaging the tufted artificial turf. For example there may be large cameras which are pointed permanently at the tufted artificial turf. This may be beneficial because there may be existing cameras such as security cameras which can be used for this purpose. This may remove the need to install additional cameras.

[0049] In another embodiment the self-driving robot comprises a robot-mounted camera configured for imaging a region of the tufted artificial turf. The optical detection system comprises the robot-mounted camera. This

embodiment may be beneficial because the self-driving robot may be self-contained. For example the self-driving robot may be programmed to traverse the entire range of the tufted artificial turf and as it does this it may check to see that the artificial turf infill is sufficiently distributed. If it isn't it may take such corrective action such as brushing the artificial turf infill to be more evenly distributed and/or to add more artificial turf infill by for example distributing it using the hopper.

[0050] In another embodiment the self-driving robot further comprises a light source configured for illuminating the region of the tufted artificial turf. This embodiment may be beneficial because it may enable the self-driving robot to function at night. The use of a light source may also improve the ability of the optical detection system to properly detect the indicator yarn fibers. For example if there is insufficient light the optical detection of the indicator yarn fibers may not function properly.

[0051] In another aspect the indicator yarn fibers may contain a dye which responds to a particular frequency of light which may be provided by the light source. For example, the indicator yarn fibers may contain a fluorescent dye and the light source may be a so-called black light. This may cause the indicator yarn fibers to fluoresce which may make them easy to detect in an optical image.

[0052] In another embodiment the light source is a black light.

[0053] In another embodiment the light source is a visible spectrum light source.

[0054] In another embodiment the optical detection system comprises a filter configured for identifying the yarn fibers in the optical data. For example the filter may filter light so that only a light within a particular frequency range is emitted to the optical detection system. For example the optical detection system could use a filter which is tuned to receive light from a particular fluorescence emission.

[0055] In another embodiment execution of the machine-executable instructions causes the processor to identify the location of the indicator yarn fibers in the optical data by identifying regions with a predetermined color range. For example the optical detection system could be a color camera. The location of the indicator yarn fibers could then be determined by looking for portions of the acquired optical data which have color within a predefined range.

[0056] In another aspect, the invention provides for an artificial turf system comprising: a tufted artificial turf (100) according to an embodiment or example; and an artificial turf maintenance robot system according to an embodiment or example.

[0057] In another embodiment, the optical detection system of the artificial turf maintenance robot system is configured for detecting the indicator yarn fibers. For example, if the optical detection system comprises a color camera, images acquired by the color camera may be processed to identify the location of a pixels which have a color within a predetermined range of the color of indi-

cator yarn fibers.

Brief description of the drawings

[0058] In the following embodiments of the invention are explained in greater detail, by way of example only, making reference to the drawings in which:

- Figure 1 depicts a cross-sectional view of an artificial turf according to an embodiment of the invention.
- Figure 2 depicts a cross-sectional view of an artificial turf according to another embodiment of the invention.
- Figure 3 depicts three alternative ways how indicator yarn fibers and face yarn fibers can be integrated in a carrier.
- Figure 4 illustrates an example of a turf maintenance robot system.
- Figure 5 illustrates a further example of a turf maintenance robot system.

Detailed Description

[0059] Like numbered elements in these figures are either equivalent elements or perform the same function. Elements which have been discussed previously will not necessarily be discussed in later figures if the function is equivalent.

[0060] **Figure 1** depicts a cross-sectional view of an artificial turf 100 according to an embodiment of the invention. The artificial turf 100 comprises texturized indicator yarn fibers 106 having an indicator yarn fiber height L2 and straight (non-texturized) face yarn fibers 104 having a face yarn fiber height L3. In case the face yarn fibers 104 are texturized as well, preferably, the fibers of the face yarn are made of a mixture of PE/PA with compatibilizer as disclosed in EP 3122942. Surprisingly PE/PA monofilaments have the following advantages in this context: the texturing has more long term stability even if subjected to mechanical stress and weathering (sunshine). The indicator yarn fibers are shorter than the face yarn fibers by a length L1. The depicted texturized indicator yarn fibers 206 can be textured monofilaments or textured split film tapes or bundles of textured monofilaments or textured split film tapes. The indicator yarn can be made of PE monofilaments (in particular LLDPE) or another material as it is less stressed both mechanically and by weathering. Moreover, indicator yarn lacking PA may shrink stronger if exposed to heat. This effect may be used for generating an artificial turf with two types of fibers which are adapted to form an indicator yarn zone of a clearly defined, uniform fiber height L2, and for generating face yarn fibers having a defined, uniform fiber

height L3. The face yarn fibers and indicator yarn fibers are integrated, e.g. tufted, in a carrier 102, e.g. a mesh made of synthetic or plant-based materials. In addition, the artificial turf 100 comprises a fill layer comprising artificial turf infill 108, which has an installation height L4 above the carrier 102, which is greater than the indicator yarn fiber height L2, if the turf infill is installed correctly. The indicator yarn fibers serve the purpose of holding or immobilizing the infill and prevent or reduce splashing and limit redistribution of the infill when the artificial turf is in use, thereby lessen an uneven distribution of the infill. It is further depicted that the height difference D34 between the face yarn fiber height and the installation height L3 is equal or greater than 0.1 cm, here approximately between 1.7 cm and 2.2 cm. This height difference D34 provides the rolling resistance for the rolling ball. The shown artificial turf might thus be an artificial turf used for soccer. Further, the artificial turf may comprise a backing (as depicted in figure 2).

[0061] **Figure 2** depicts a cross-sectional view of an artificial turf 100 according to another embodiment of the invention. The artificial turf 100 comprises a backing 110, e.g. a layer of solidified latex or polyurethane having been added in liquid state onto the lower side of the carrier 102 after the fibers 104, 106, which are described in Fig. 1, have been tufted into the carrier. The side of the carrier 102 from which the fibers 104, 106 protrude is referred herein as the "upper side" of the carrier/of the artificial turf, while the other side, where only u-shaped portions of the fibers forming tuft knots and/or a secondary backing 310 may be visible, is referred herein as the "lower side" of the artificial turf. The artificial turf 100 comprises a backing 110, e.g. a layer of hardened latex or polyurethane, that contacts and surrounds the U-shaped fibers on the lower side of the artificial turf, thereby strongly fixing the fibers in the carrier. Thus, two fibers extend vertically on the upper side per U-shaped fiber. In addition, the artificial turf 100 comprises a filler 308, e.g. a sand-rubber-granule mixture. The infill may fill free space between indicator yarn fibers and/or face yarn fibers. As the face yarn is straight, the installation height L4 of the infill 108 almost reaches the tips of the face yarn fibers 104 in order to stabilize the fibers. The depicted artificial turf may for example be a hockey turf, for which the height difference D34 between the face yarn fiber height L1 and the installation height L4 of the infill 108 is approximately between 0.5 cm and 1.4 cm. The depicted artificial turf may however also be an artificial turf used for tennis or puddle tennis, for which the height difference D34 between the face yarn fiber height L1 and the installation height L4 of the infill 108 is approximately between 0.1 cm and 1.0 cm. Thanks to the textured indicator yarn fibers, the infill granules are somewhat stabilized and protected from being delocalized by a ball or other object hitting the surface of the artificial turf. However, extensive use of the artificial turf may delocalize the infill 108 in some regions, as indicated by region 109. However, since the indicator yarn fibers 106 have a first optically

visible contrast relative to the face yarn fibers 104 and the indicator yarn fibers 106 have a second optically visible contrast, which can be the same as the first optically visible contrast, relative to the artificial turf infill 108, the region 109 can be easily identified by the user or by an robot, which can identify and compare optically visible contrasts. Thus, the region 109 can be refilled or the infill 108 can be redistributed such that the optically visible contrast disappears. This can be either done by the user or a maintenance robot.

[0062] Figure 3 depicts three alternative ways (Fig. 3A to 3C) how textured indicator yarn fibers 106 and straight face yarn fibers 104 can be integrated in a carrier in the form of rows.

[0063] Figure 3A depicts an artificial turf wherein textured face yarn fibers and textured thatch yarn fibers are tufted in straight parallel rows. The face yarn fibers 104 are depicted as tufts "A", which are tufted in second rows 504 and the indicator yarn fibers 106 are depicted as tufts "B", which are tufted in first rows 502. The first rows 502 and the second rows 504 may be alternating in the plane of an artificial turf. The face yarn fibers are longer than the indicator yarn fibers. The fibers are integrated into the carrier by a tufting process, whereby bundles of fibers of the same type are tufted into the carrier and are then cut. Each row 502, 504 comprises only fibers of one particular type, i.e., either indicator yarn fibers or face yarn fibers. The distance between tufting rows of the same fiber type can be e.g. 1.9 cm and can be about 0,95 cm between neighboring rows of face/indicator yarn.

[0064] Figure 3B depicts another artificial turf row 508 wherein face yarn fibers 104 and textured indicator yarn fibers 106 are tufted in tufts, wherein tuft A indicates a face yarn fiber tuft and tuft B indicates an indicator yarn fiber tuft. The tufts A and B are alternating in the same row 508.

[0065] Figure 3C depicts another (third) artificial turf row 506 wherein face yarn fibers 104 and textured indicator yarn fibers 106 are tufted in the same tuft, wherein each tuft AB indicates two face yarns tufted into four face yarn fibers 104 protruding from the carrier and two indicator yarns tufted into four indicator yarn fibers 104 protruding from the carrier.

[0066] The in Figures 3A to 3C depicted rows 502, 504, 506, 508 may be alternating in the plane of an artificial turf or they may be used in pairs, e.g. as described for rows 502 and 504 in Fig. 3A. It is further feasible that the rows are straight lines and/or zig-zag lines (not depicted).

[0067] Figure 4 illustrates an example of an artificial turf maintenance robot system 300. In this figure, there is also a tufted artificial turf 100. The artificial turf maintenance robot system 300 comprises a self-driving robot 304 that has been placed on the tufted artificial turf 100. The self-driving robot 304 comprises a processor 308. The processor is configured for controlling and operating the self-driving robot 304. The self-driving robot 304 further comprises a memory 310 that contains machine-executable instructions 312. The memory 310 is acces-

sible by the processor 308. The machine-executable instructions 312 enable the processor 308 to control and operate the self-driving robot 304. The self-driving robot 304 could be configured to move about using a variety of different wheels and/or tracks. In the example shown in Figure 4 it is shown as being moved on wheels 314. The exact number of wheels 314 may be different in different embodiments. For example the self-driving robot 304 may have four wheels in some examples and may have three wheels in a different example. The self-driving robot 304 is also shown as containing optionally a brush 316. The brush in this example is a cylindrical brush that can be rotated. In other examples the brush may be a brush which is used to plough or bulldoze artificial turf infill. Some of the wheels 314 may be connected to a drive system 318 which enables the wheels 314 to propel the self-driving robot 304. In other examples some of the wheels 314 may also be steerable, although this is not illustrated in this figure. In this example the brush 316 is also connected to a drive system 320 which enables the brush 316 to be controllably rotated. This may be useful in distributing artificial turf infill. The self-driving robot 304 is also shown as optionally containing a hopper 322. The hopper is configured for receiving artificial turf infill 108. At the bottom of the hopper 322 is a dispenser 326. For example this may be a controllable outlet which enables a certain amount of artificial turf infill 108 to fall onto the surface of the tufted artificial turf 100.

[0068] The self-driving robot 304 is shown as containing a robot-mounted camera 328 which is an example of an optical detection system. The robot-mounted camera 328 is mounted such that it images a field of view 303 in front of the self-driving robot. As the self-driving robot 304 moves across the tufted artificial turf 100 it can detect the presence of exposed indicator yarn fibers. If it detects exposed indicator yarn fibers then the self-driving robot 304 may either use the hopper 322 to dispense additional artificial turf infill 108 and/or to activate the brush 316. The self-driving robot 304 is shown as also optionally containing a light source 332. This for example may enable the use of the self-driving robot 304 when it is dark and may save the cost of illuminating for example a large sport field such as a large soccer field. In other instances the light source 332 may also be such light sources as a black light, which may be used to illuminate or activate fluorescent dyes that may be present in the indicator yarn fibers.

[0069] The combination of the tufted artificial turf 100 and the artificial turf maintenance robot system 300 may also form an artificial turf system 334.

[0070] Figure 5 illustrates a further example of an artificial turf maintenance robot system 400. The artificial turf maintenance robot system 400 in this example comprises a self-driving robot 304 as well as an optical detection system 402 and a computer 404. The computer 404 is shown as further containing a processor 308' and a memory 310'. The computer 404 is further shown as comprising a hardware interface 406 and a radio com-

munication system 408. The hardware interface 406 enables the processor 308' to control and operate other components of the artificial turf maintenance robot system 400. For example there is an optical detection system 402 connected to the hardware interface 406. The optical detection system 402 is intended to be representative of a camera or other optical detection system which is not part of the self-driving robot 304. For example the optical detection system 402 could represent a camera on a drone and/or a fixed camera pointed at the tufted artificial turf 100. In some instances, particularly when the optical detection system 402 is a drone-mounted camera, the communication between the drone-mounted camera and the processor 308' may be via a radio communication system 408. The computer 404 is further shown as comprising a radio communication system 408 which forms a radio communication link 410 with an additional radio communication system 412 on the self-driving robot 304. In some instances the local processor of the self-driving robot 304 may control it. In other examples the processor 308' may control the operation and function of the self-driving robot 304 remotely. In some examples the combination of the artificial turf maintenance robot system 400 and the tufted artificial turf 100 may again form an artificial turf system 334.

[0071] The memory 310 is shown as comprising machine-executable instructions 312'. Again the machine-executable instructions 312' enable the processor 308' to control the operation and function of the artificial turf maintenance robot system 400. The operation and functions performed by the processor 308' in this example may also be distributed to the local processor 308 of the self-driving robot 304.

[0072] The memory 310 is further shown as containing image data 414. For example the image data 414 may be a color image acquired by the optical detection system 402. The processor 308' is then controlled by the machine-executable instructions 312' to calculate optical data 416 from the image data 414. In the case when the image data 414 is a color image this may be performed by looking for regions within the image data 414 that contain a color within a predefined range which is used to identify the indicator yarn fibers in the tufted artificial turf 100. The machine-executable instructions 312' then may control the processor 308' to generate control commands 418 from the optical data 416. The processor 308' can then control the self-driving robot 304 by sending the control commands 418 via the radio communication link.

List of reference numerals

[0073]

100 tufted artificial turf
102 carrier
104 face yarn fibers
106 indicator yarn fibers
108 artificial turf infill

109 region
110 backing layer
L1 height difference (=L3-L2)
L2 indicator yarn fiber height
5 L3 face yarn fiber height
L4 infill installation height
D34 height difference between L3 and L4
300 artificial turf maintenance robot system
304 self-driving robot
10 308 processor
308' processor
310 memory
310' memory
312 machine executable instructions
15 312' machine executable instructions
314 wheel
316 brush
318 drive system
320 drive system
20 322 hopper
326 dispenser
328 robot mounted camera (optical detection system)
330 field of view
25 332 light source
334 artificial turf system
400 artificial turf maintenance robot system
402 optical detection system
404 computer
30 406 hardware interface
408 radio communication system
410 radio communication link
412 radio communication system
414 image data
35 416 optical data
418 control commands
502 first rows
504 second rows
506 third rows
40 508 another turf row

Claims

- 45 1. Tufted artificial turf (100) comprising:
- an artificial turf carpet comprising:
 - a carrier (102),
 - indicator yarn fibers (106), and
 - face yarn fibers (104); and
 - an artificial turf infill (108) distributed between the indicator yarn fibers and the face yarn fibers;
- 55 wherein the face yarn fibers and the indicator yarn fibers being tufted into the carrier such, that the face yarn fibers (104) protrude from the carrier (102) with

- a face yarn fiber height (L3) and the indicator yarn fibers (106) protrude from the carrier with an indicator yarn fiber height (L2), wherein the face yarn fiber height (L3) being larger than the indicator yarn fiber height (L2);
 wherein the artificial turf infill (108) has an installation height (L4) above the carrier (102), wherein the installation height (L4) is greater than the indicator yarn fiber height (L2); and
 wherein the indicator yarn fibers (106) have a first optically visible contrast relative to the face yarn fibers (104) and
 wherein the indicator yarn fibers (106) have a second optically visible contrast relative to the artificial turf infill (108).
2. Tufted artificial turf (100) according to claim 1, wherein the face yarn fibers (104) have a optically visible contrast relative to the artificial turf infill (108).
 3. Tufted artificial turf (100) according to claim 1 or claim 2, wherein the indicator yarn fibers (106) are texturized or straight fibers and the face yarn fibers (104) are straight fibers.
 4. Tufted artificial turf (100) according to claim 3, wherein the indicator yarn fibers (106) are texturized and the face yarn fibers (104) are straight fibers.
 5. Tufted artificial turf (100) according to claim 3 or claim 4, wherein the texturized indicator yarn fibers (106) are produced from stretched and textured monofilament yarn comprising a polymer mixture, wherein the polymer mixture is at least a three-phase system, wherein the polymer mixture comprises a first polymer, a second polymer, and a compatibilizer, wherein the first polymer and the second polymer are immiscible, wherein the first polymer forms polymer beads surrounded by the compatibilizer within the second polymer
 6. Tufted artificial turf (100) according to one of claims 1 to 4, wherein the height difference (D34) between the face yarn fiber height (L3) and the installation height (L4) is equal or greater than 0.1 cm.
 7. Tufted artificial turf (100) according to one of claims 1 to 6, wherein the carrier comprises tufts, comprising at least two indicator yarn fibers (106), which are integrated into the carrier in the form of first rows (502) and wherein the carrier further comprises tufts, comprising at least two face yarn fibers (104), which are integrated into the carrier in the form of second rows (504), wherein the first rows and second rows alternate and wherein the first rows and second rows are parallel to each other.
 8. Tufted artificial turf (100) according to one of claims 1 to 6, wherein the carrier comprises tufts, comprising in the same tuft at least two indicator yarn fibers (106) and at least two face yarn fibers (104), which are integrated into the carrier in the form of third rows (506), whereby the third rows are parallel to each other.
 9. A method for maintaining a tufted artificial turf (100) according to claim 1, wherein the method comprising:
 - i. Inspecting the tufted artificial turf (100) to identify a region (109), where the optically visible contrast of the indicator yarn fibers (106) relative to the infill (108) is optically detectable;
 - ii. redistributing and/or providing additional infill in order to cover the indicator yarn fibers (106) such that the optically visible contrast disappears.
 10. The method for maintaining a tufted artificial turf (100) according to claim 9, wherein the step of inspecting is performed by visual inspection.
 11. The method for maintaining a tufted artificial turf (100) according to claim 9, wherein the step of inspecting is performed by means with an optical sensor.
 12. The method for maintaining a tufted artificial turf (100) according to claim 11, wherein the means with an optical sensor are arranged within a maintenance robot.
 13. The method for maintaining a tufted artificial turf (100) according to claim 11 or claim 12, wherein step ii. is performed with a maintenance robot.
 14. An artificial turf maintenance robot system (300, 400) for maintenance of a tufted artificial turf (100) filled with an artificial turf infill (108), wherein the turf maintenance robot system comprises:
 - a self-driving robot (304) configured for distributing artificial turf infill within the tufted artificial turf;
 - a processor (308, 308') for controlling the turf maintenance robot system; and
 - a memory (310) containing machine executable instructions (312, 312') for execution by the processor, wherein execution of the machine executable instructions causes the processor to:
 - receive optical data (416) descriptive of a location of indicator yarn fibers; and
 - control the self-driving robot using the optical data to distribute artificial turf infill to optically obscure the indicator yarn fibers.

15. The artificial turf maintenance robot system of claim 14, wherein the self-driving robot comprises a brush (316) configured for distributing the artificial turf infill, wherein execution of the machine executable instructions further causes the processor to control brushing of the tufted artificial turf with the brush to optically obscure the indicator yarn fibers.
16. The artificial turf maintenance robot system of claim 14 or 15, wherein the self-driving robot comprises a hopper (322) configured for storing the artificial turf infill, wherein the self-driving robot further comprises a controllable dispenser (326) for dispensing the artificial turf infill from the hopper, wherein execution of the machine executable instructions further causes the processor to control the controllable dispenser to dispense artificial turf infill to optically obscure the indicator yarn fibers.
17. The artificial turf maintenance robot system of any one of claims 14 to 16, wherein the turf maintenance robot system further comprises an optical detection system (328, 402) configured for acquiring the optical data, wherein execution of the machine executable instructions further causes the processor to control the optical detection system to acquire the optical data.
18. The artificial turf maintenance robot system of claim 17, wherein the artificial turf maintenance robot system comprises a drone, wherein the drone comprises a drone camera (402) for at least partially imaging the tufted artificial turf, wherein the optical detection system comprises the drone camera.
19. The artificial turf maintenance robot system of claim 17 or 18, wherein the optical detection system comprises one or more fixed cameras (402) configured for at least partially imaging the tufted artificial turf.
20. The artificial turf maintenance robot system of claim 17, 18, or 19, wherein the self-driving robot comprises a robot mounted camera (328) configured for imaging a region (330) of the tufted artificial turf, and wherein the optical detection system comprises the robot mounted camera.
21. The artificial turf maintenance robot system of claim 20, wherein the self-driving robot further comprise a light source (332) configured for illuminating the region of the tufted artificial turf.
22. The artificial turf maintenance robot system of claim 21, wherein the light source is any one of the following: a blacklight and a visible spectrum light source.
23. The artificial turf maintenance robot system of any one of claims 14 thorough 22, wherein the optical detection system comprises a filter configured for identifying the indicator yarn fibers in the optical data.
24. The artificial turf maintenance robot system of any one of claims 14 through 22, wherein execution of the machine executable instructions causes the processor to identify the location of the indicator yarn fibers in the optical data by identifying regions within a predetermined color range.
25. An artificial turf system (334) comprising:
- a tufted artificial turf (100) according to any one of claims 1 to 8; and
 - an artificial turf maintenance robot system (300, 400) according to any one of claims 14 through 24.

Fig. 1

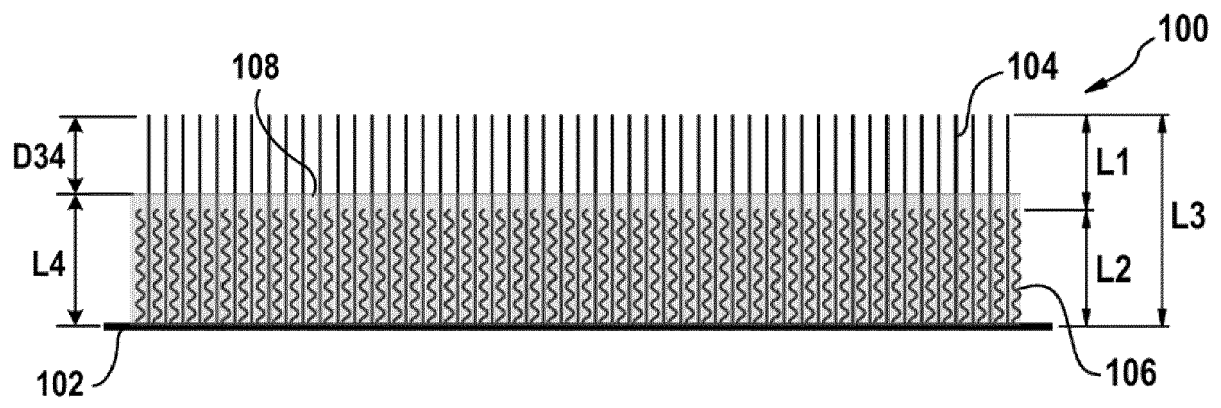


Fig. 2

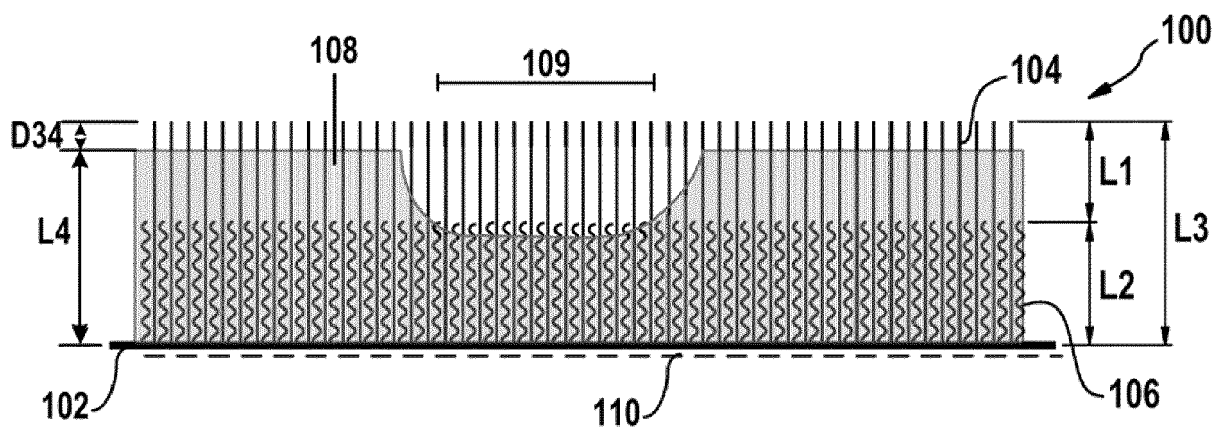


Fig. 3

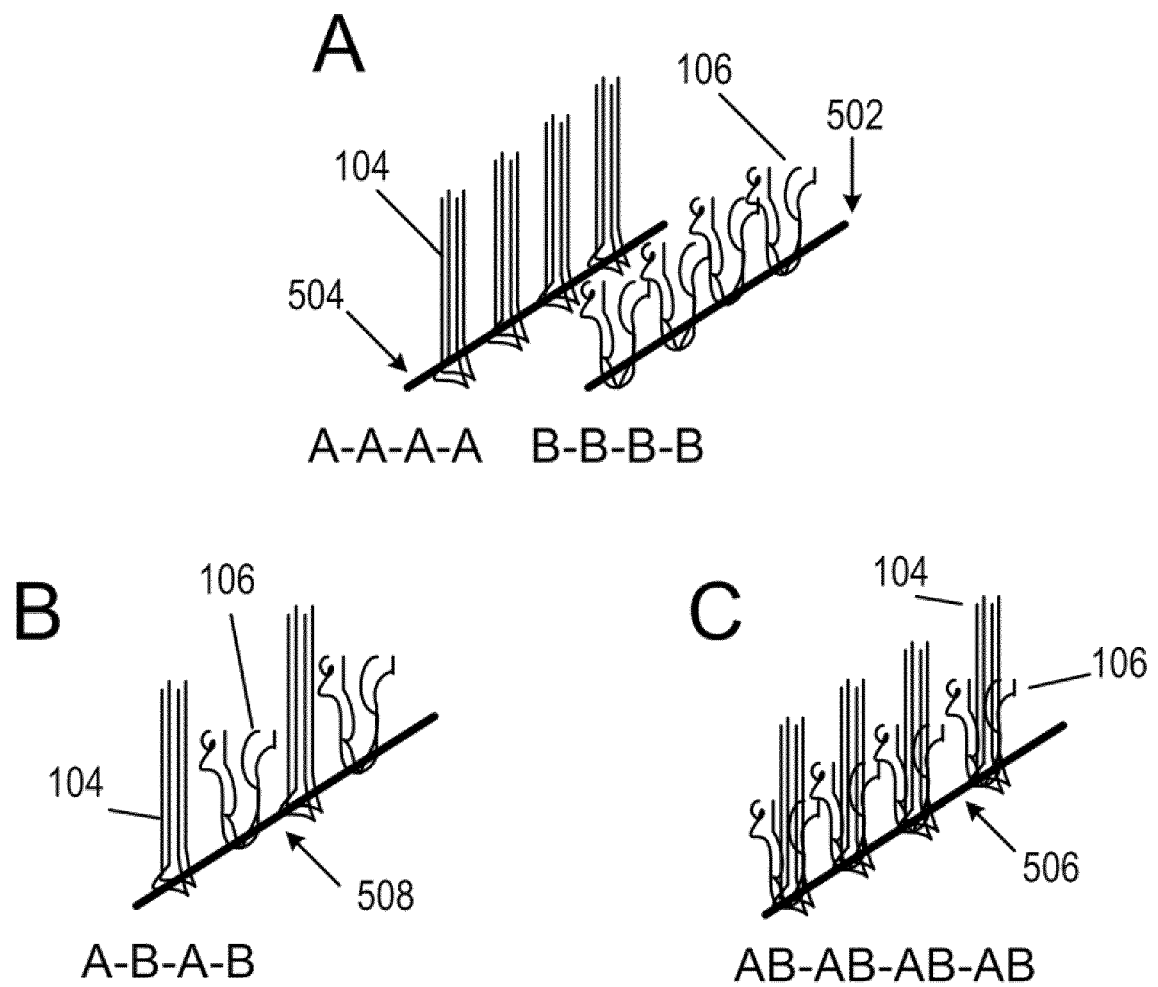


Fig. 4

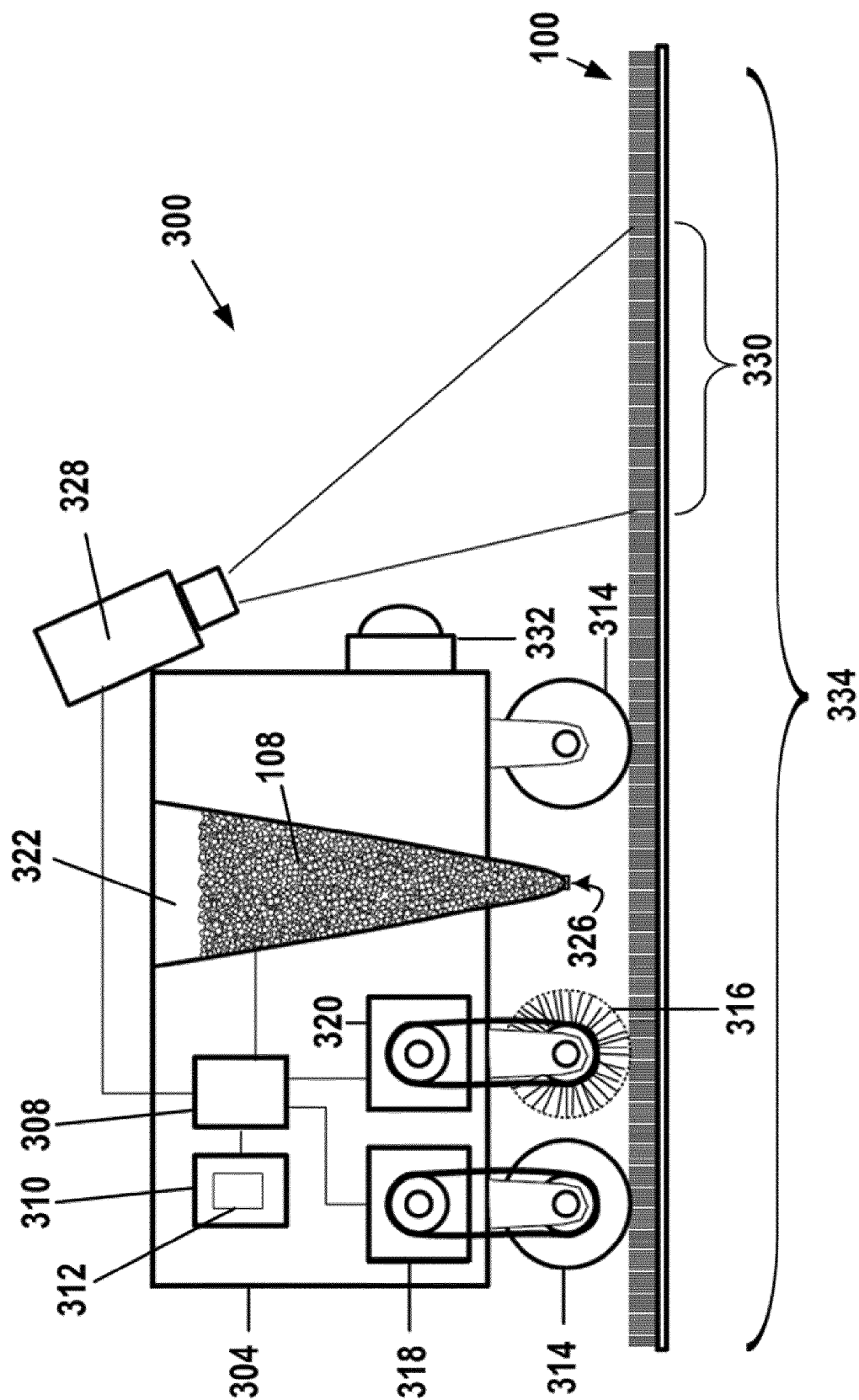
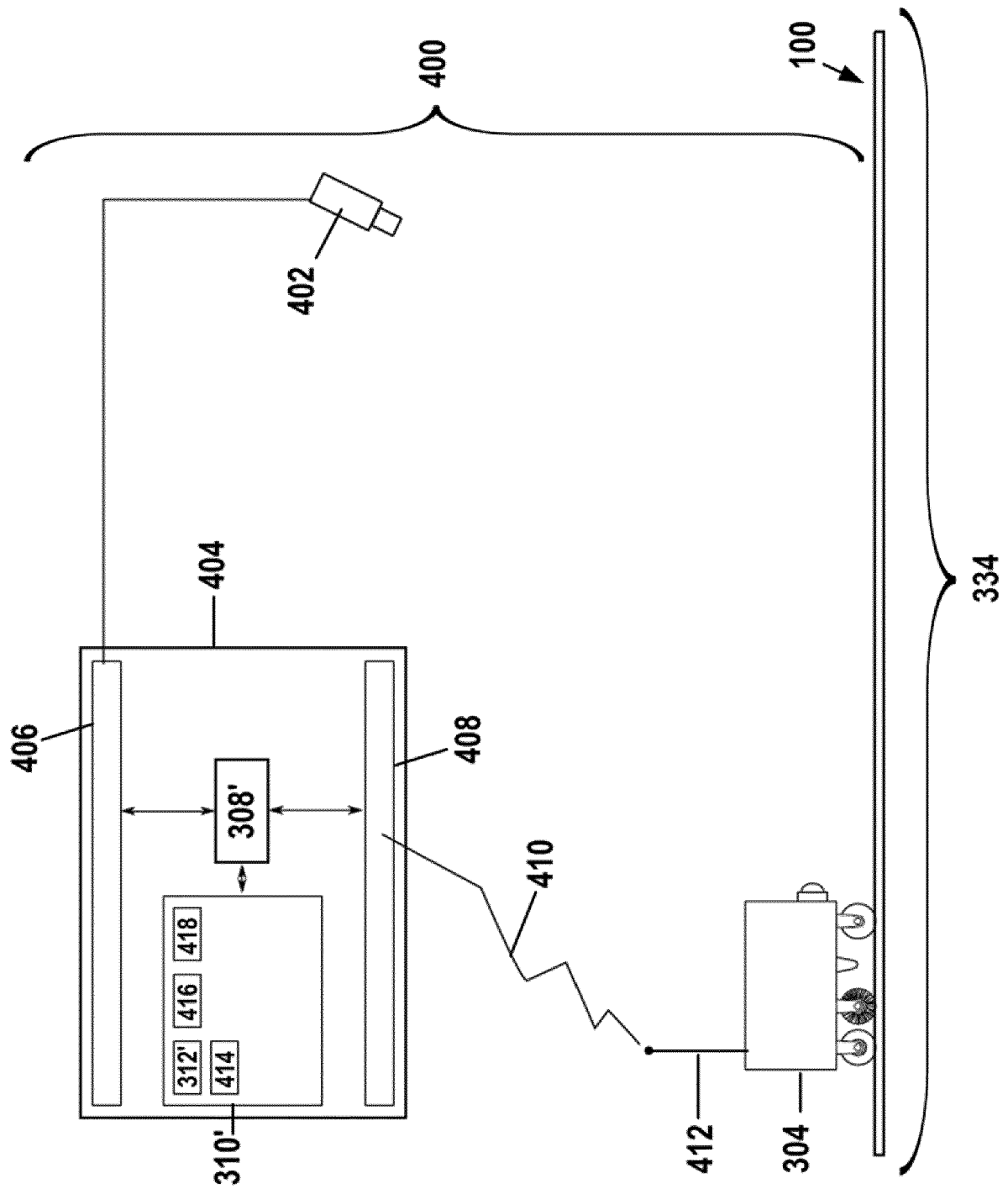


Fig. 5





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Application Number
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