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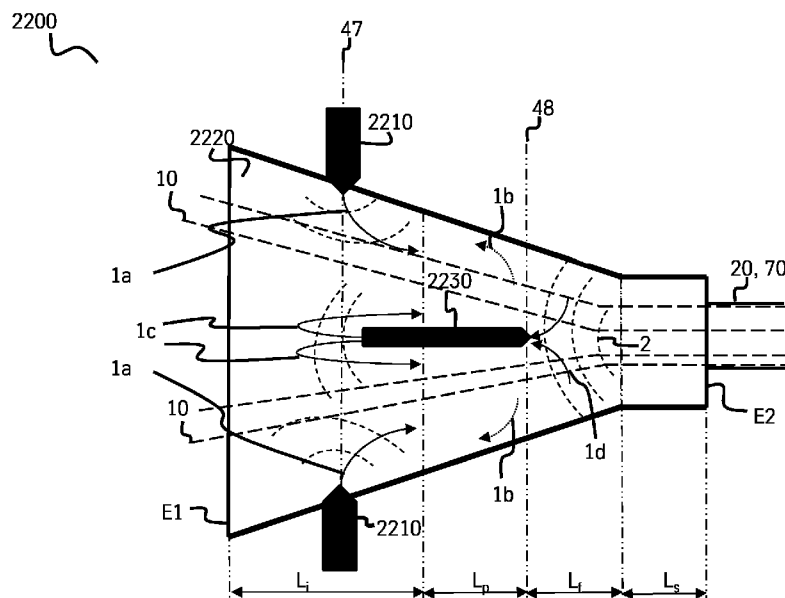


Fig. 1

Pulling direction D_p

(57) Abstract: The invention relates to a core impregnator (2200) for use in a process of producing a composite elevator belt. The core impregnator comprises at least one opening for supplying a resin material to an inner cavity (2220) of the impregnator; a point of fiber entry (E1); a point of fiber exit (E2); wherein the point of fiber entry has a height larger than the point of fiber exit such that the inner cavity and thus the impregnator (2200) is tapered. The invention also relates to a process for producing a composite elevator belt using said tapered core impregnator (2200).

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CORE IMPREGNATOR AND METHOD OF PRODUCING A COMPOSITE ELEVATOR BELT
USING A TAPERED CORE IMPREGNATOR

The present invention is generally directed to composite elevator belts for use in lifting and lowering an elevator car. More particularly, the present invention relates to a tapered core impregnator for use in a process of producing a composite elevator belt comprising at least one load carrier. It also relates to a production process for making a composite elevator belt comprising at least one load carrier.

Elevators for vertically transporting people and goods are an integral part of modern residential and commercial buildings. A typical elevator system includes one or more elevator cars raised and lowered by a hoist system. The hoist system typically includes both driven and idler sheave assemblies over which one or more tension members attached to the elevator car are driven. Tension members can also be attached to the counterweight or building structure itself. The elevator car is raised or lowered due to traction between the tension members and drive sheaves. A variety of tension member types, including wire rope, V-belts, flat belts, and chains, may be used, with the sheave assemblies having corresponding running surfaces to transmit tractive force between the tension members and the sheave assemblies.

Accordingly, minimizing the bend radius of elevator tension members, and conversely increasing tension member flexibility, is desirable. Among current tension member designs, composite belts having fiber or wire strands encased in a resin or polymer generally offer the greatest flexibility. An example of a known tension member is described in U.S. Patent No. 9,126,805 to Pelto-Huikko et al., which is directed to an elevator rope including fiber reinforcements in a polymer matrix material. A coating material surrounds the polymer matrix material to increase friction and improve wear resistance of the tension member.

When a tension member is engaged with a sheave, the tension member is subjected to compression along an outer area in contact with the sheave and tension along an outer area away from the sheave. Frictional tractive force between the tension member and the pulley can impart additional compression to the outer surface of the tension member where the tension member is bent around the sheave. Many materials used to manufacture elevator tension members are significantly stronger in tension than compression. For example, carbon fiber, which is used in many composite belt designs such as in Pelto-Huikko et al., is typically only 20-70% as strong in compression as it is in tension. Therefore, tension members are typically more likely to fail as a result of internal compression experienced during the engagement with the

sheave. Accordingly, the minimum bend radii of existing tension members is governed by internal compression loads due to bending.

Current tension members of polymer-encased fiber construction are typically produced using pultrusion processes. One such process is described in U.S. Patent No. 3,960,629 to Goldworthy, which teaches a pultrusion method utilizing a thermosetting resin applied to conductive strands and cured via electrical induction. U.S. Patent No. 8,343,410 to Herbeck et al. teaches a similar induction-based curing process for pultruded composite fiber articles. However, current pultrusion methods often have limited production speeds, and many current processes are suitable only for production of flat profiles. Moreover, many current pultrusion processes require the use of resin additives to prevent sticking of the resin to the various machine components used in the pultrusion process. Dilution of the resin with such additives compromises the mechanical properties of the cured thermoset, resulting in decreased breaking strength of the produced articles.

A limiting factor in the design of current elevator systems is the minimum bend radius of the tension members. If a tension member is flexed beyond its minimum bend radius, the compressive forces within the tension member may exceed the breaking strength of the tension member material. Continuous operation of the tension members below their minimum bend radii can cause fatigue at an increased and unpredictable rate and, under extreme circumstances, may result in elastic deformation and failure. Thus, minimum size of the sheaves useable in an elevator system is governed by the minimum bend radius of the tension members. For several reasons, sheaves having a smaller diameter allow for more economical elevator system designs. First, the overall component cost of an elevator system can be significantly reduced by using smaller diameter sheaves and sheave assemblies. Second, smaller diameter sheaves reduce the motor torque necessary to drive the elevator system, thereby permitting use of smaller drive motors and allowing for smaller hoistway dimensions. Additionally, decreasing the bend radius of the tension members generally permits easier installation and decreases the spool size of the tension members.

Known processes of producing composite elevator belts involve the production of layers having different fiber volume fractions (V_f). A fiber volume fraction is the percentage of fiber volume in the entire composite volume comprising fibers and matrix material. These layers are subsequently glued together to form the load carrier of the composite elevator belt. Such layered designs involve several manufacturing steps and the production costs are high. In addition,

differing fiber volume fractions (V_f) throughout the cross-section of the composite elevator belt can reduce the belt flexibility. It is thus desired to produce a composite elevator belt comprising one or more load carriers in a “one pot process” thereby increasing production speed.

Furthermore it is desired to produce in a “one pot process” a composite elevator belt having at least one load carrier with a controllable fiber volume fraction V_f throughout its cross-section, thereby achieving a belt with a controllable cross-section orientation as well as an improvement in its flexibility.

The invention provides a solution to the above problem and is described in the following embodiments. The invention relates to:

- [1] A core impregnator for use in a process of producing a composite elevator belt. The core impregnator preferably comprises:
- an inner cavity;
 - at least one opening, preferably a nozzle for supplying a resin material to the inner cavity;
 - a point of fiber entry;
 - a point of fiber exit.

Preferably, the point of fiber entry has a height larger than the point of fiber exit such that the inner cavity of the core impregnator is tapered. At the point of fiber exit, the fibers are preferably in a desired orientation which will become the fiber orientation of the cross-section of the composite elevator belt. As the fibers pass from the point of entry to the point of exit, they can be advantageously orientated via control of the supply of resin material. This will be described in more detail in the figure description.

- [2] The impregnator according to embodiment [1], characterized in that the height difference between the point of fiber entry and the point of fiber exit is in a range from 0.1 mm to 1.5 mm, preferably in a range from 0.2 mm to 0.7 mm, more preferably in a range from 0.3 mm to 0.5 mm. This advantageously provides for varying pressures within the inner cavity of the core impregnator, in particular when the inner cavity is supplied with resin material. As the height decreases, the pressure increases.
- [3] The impregnator according to any of the preceding embodiments, characterized in that the inner cavity comprises a tapered angle (β) wherein β preferably lies in a range of 0.01 to 2 degrees, more preferably β lies in a range 0.03 to 1 degree. This advantageously provides that the selected height of the point of fiber entry and the

selected height of the point of fiber exit will always be sufficient to achieve the advantageous varying pressure regions within the inner cavity of the core impregnator. A lower β value indicates a longer core impregnator and thus one in which the pressure differential within the cavity will be lower. This affects the distribution of the fibers throughout the cross-section of the at least one load carrier. The relationship between the tapering and pressure will be explained in more detail in the figure description.

- [4] The impregnator according to any of the preceding embodiments characterized in that it further comprises at least one pressure regulating means. An example of such a pressure regulating means is a resin backflow tube. This advantageously provides that the pressure within the impregnator is controllable. By controlling the speed of the resin material supplied to the inner cavity of the impregnator, pressure can be further controlled. Preferably, the pressure within the inner cavity of the impregnator is in the range of 0.1 to 3 MPa.
- [5] The impregnator according to any of the preceding embodiments, characterized in that the at least one pressure regulating means is located in a central cavity of the impregnator. This advantageously provides for optimum control of pressure.
- [6] The impregnator according to any of the preceding embodiments, characterized in that it comprises a plurality of zones. The zones are located in the cavity and include an injection zone L_i ; a pressurizing zone L_p ; a flow zone L_f and a stabilizing zone L_s . The injection zone L_i is preferably located at the point of fiber entry, the stabilizing zone L_s is preferably located at the point of fiber exit. The pressurizing zone L_p is preferably located between the point of fiber entry and the flow zone L_f , the flow zone L_f is preferably located between the stabilizing zone L_s and the pressurizing zone L_p .
- [7] The impregnator according to any of the preceding embodiments, characterized in that the at least one pressure regulating means is positioned within the injection zone L_i and the pressurizing zone L_p . This advantageously provides for optimum pressure control.
- [8] The impregnator according to any of the preceding embodiments, characterized in that it is adapted to withstand pressures in a range of 0.1 to 3 MPa. Preferably, the pressure varies according to the movement of the fibers and the resin material through the impregnator. In particular, the pressure varies as the fibers travel through each of the injection zone L_i ; the pressurizing zone L_p ; the flow zone L_f and the stabilizing zone L_s . This

advantageously provides for a controllable fiber volume fraction V_F of the at least one load carrier within the composite elevator belt.

- [9] The impregnator according to any of the preceding embodiments, characterized in that the pressure within the injection zone L_i is lower than the pressure within the pressurizing zone L_p and the flow zone L_f . This advantageously provides that the pressure at the point of entry is sufficient so that the fibers supplied to the impregnator are first contacted with resin material before being exposed to higher pressures.

The invention also relates to:

- [10] A production process for a composite elevator belt comprising the steps of:
- a) providing a manufacturing apparatus comprising
 - a fiber spool rack comprising a plurality of spools wherein each spool comprises a fiber;
 - a fiber arranger for arranging the fibers before they are contacted with a resin material;
 - a core impregnator according to any of embodiments [1] to [9];
 - a pultrusion die, preferably curing is performed in the pultrusion die;
 - a cooling chamber, this is preferably the final stage of curing before extrusion begins;
 - an extrusion chamber;
 - a spooler;
 - b) unwinding a plurality of fibers from the fiber spool rack;
 - c) arranging the fibers, preferably via spreading, before being supplied to the impregnator;
 - d) supplying the arranged fibers to the impregnator;
 - e) introducing a resin material to the cavity of the impregnator to saturate and encase the supplied fibers in order to provide at least one load carrier having a desired fiber volume fraction V_F wherein the at least one load carrier is preferably comprised in a core layer. The core layer material can be the same as the resin material used to saturate the fibers or different;
 - f) exiting the core layer comprising the at least one load carrier from the impregnator.
- This advantageously provides a “one pot process” for obtaining a composite elevator belt comprising at least one load carrier having a desired fiber volume fraction V_F throughout its cross-section.

[111] The production process according to embodiment [10] further comprising:

g) further treating the core layer comprising the at least one load carrier to obtain the composite belt;

h) collecting the composite belt on a spooler.

Preferably, further treating comprises at least one of shaping, curing; cooling; extrusion.

The composite elevator belt may also optionally comprise a jacket layer. This advantageously produces the “finished product” i.e., the composite elevator belt having at least one load carrier with a desired fiber volume fraction throughout its cross-section.

The invention is described in more detail with the help of the figures, wherein it is shown schematically:

Fig. 1 a schematic representation of a cross-section of a core impregnator according to the invention;

Figs. 2a-2b a schematic representation of a core impregnator according to the invention comprising a pressure regulating means;

Fig. 3 a schematic representation of a manufacturing apparatus used in the process according to the invention;

Fig. 4 a step diagram of a process for producing a composite elevator belt using a manufacturing apparatus comprising a core impregnator according to the invention.

Figs 5a-5c schematic representations of a composite elevator belt comprising differing fiber volume fractions V_f .

Fig. 1 shows a core impregnator 2200 according to the invention comprising an inner cavity with walls 2220, a point of fiber entry E1 and a point of fiber exit E2 wherein fibers 10 are fed into the cavity 2220 at the point of fiber entry E1. The height difference between the points E1 and E2 provides the tapering of impregnator 2200. The impregnator 2200 comprises two openings 2210 into the cavity 2220. Through the cavity openings 2210, the cavity is supplied with resin material. An example of an opening 2210 includes a nozzle. In this particular example, the opening 2210 is an automated nozzle. A first nozzle 2210 is located on a tapered side which is adjacent to the point of fiber entry E1. A second nozzle 2210 is located on an opposite tapered side adjacent to the point of fiber entry E1. The nozzles 2210 lie on an injection plane 47 and provide a supply of resin material (shown by arrow 1a) to an injection zone Li of the cavity 2220. The impregnator comprises four zones, the injection zone with the length Li; a pressurizing zone

with the length L_p ; a flow zone with the length L_f ; and a stabilizing chamber zone with the length L_s . The length of the tapered part L_T of the impregnator is:

$$L_T = L_i + L_p + L_f.$$

The total length L of the impregnator is:

$$L = L_T + L_s.$$

As the fibers move into the cavity 2220, the cavity is not yet pressurized since the fibers have not entered the pressurizing zone L_p . The resin material (not shown) contacts the passing fibers 10 in the injection zone L_i . The fibers move at a speed V_x wherein V_x is preferably in the range from 0.5 to 4 m/min in the pulling direction D_p . The pressure from the incoming resin material from the nozzles 2210 causes the fibers 10 to be pushed to the central area of the cavity 2220, thus providing at least one load carrier 70 having a higher fiber density in its center, i.e., a higher fiber fraction volume V_f , e.g. 70 %. It also ensures that the volume of resin supplied to the cavity is sufficient to maintain the stability pressurizing zone L_p throughout its length. If the volume of supplied resin is too high, the pressurizing zone L_p becomes longer and if the volume of supplied resin is too low, the pressurizing zone L_p becomes smaller. All fibers 10 within the impregnator 2200 are saturated with resin material. The at least one load carrier 70 is preferably comprised within a core layer 20, wherein the core layer is preferably comprised of the same resin material. It is also envisaged that the core layer can be comprised of a different material.

Due to the tapered shape of the impregnator 2200, the volume of the cavity 2220 decreases towards the point of fiber exit E_2 , this causes the pressure P_T to rise and at this point the fibers 10 enter the pressurized zone L_p . Here, the impregnated fibers 10 are pressurized which helps to saturate them with the resin material and release any air trapped in the fiber-resin mixture. When the pressure P_T reaches a certain level for example between 0.2 and 4.0 MPa, or between 0.3 and 3.0 MPa, and the pulling force in direction D_p provided by the tractor 2500 (shown in Fig. 3) as well as fiber velocity remains constant and the pressure P_T reaches a critical level. This prevents a fraction of the injected resin from moving through the impregnator and consequently the length of the pressurizing zone L_p increases, thus unwanted resin backflow on the inner walls of the cavity 2220 occurs, see the dotted arrows 1b and backflow plane 48. Resin backflow causes the impregnated fibers 10 to be pushed away from the central area of the cavity 2220 towards the inner walls. As a result, the fiber volume fraction V_f of the load carrier is higher at the outside than in the center and this produces a composite belt 100 having reduced bending performance.

Therefore, the impregnator 2200 further comprises at least one pressure regulating means 2230. Preferably, the pressure regulating means 2230 is adapted to allow for a continuous backflow of resin material which reduces the pressure by 0.1 to 2 MPa in the flow zone L_f and creates a resin flow to the center of the flow zone. The resin flow pulls the fibers to the center of the cavity 2220 which allows adjustment to a desired fiber volume fraction distribution throughout the cross section of the load carrier. Thus, the fiber volume fraction is mainly adjusted in the flow zone L_f . An example of a pressure regulating means 2230 can be a tube. The pressure regulating means 2230 used in this example comprises a plurality of tubes positioned in a row across the center of the cavity 2220. This is shown more clearly in Figs. 2a and 2b. For illustration purposes, only one tube 2230 is shown in fig. 1. The resin travels through the tubes 2230 from the high-pressure zone L_p or the beginning of the flow zone L_f (see arrows 1d) back to the low pressure zone of the injection zone L_i . The resin volume which flows back to the injection zone L_i is also controlled by the inner cross section of the tubes as well as the number of tubes. The resin entrance plane of the tubes is between the pressure chamber and the flow chamber zone. The high-pressure zone can also comprise the flow zone L_f . The number of pressure regulating means 2230 used depends on their diameter and the pressure differential between the injection zone L_i and the flow zone L_f .

The backflow resin exits the tubes 2230 in the injection zone L_i and travels once again in the pulling direction D_p (arrows 1c). This backflow resin improves the fiber saturation of the incoming fibers in the central area of the cavity 2220 while the outer areas of the incoming fibers 10 are saturated by the resin supplied by the nozzles 2210. This provides for better overall saturation of the fibers 10 and thus a higher quality of the load carrier 70 and consequently a higher quality of the belt 100. The backflow of resin in the center also lowers the pressure in the cavity 2220 and ensures the fibers 10 maintain the desired fiber volume fraction V_f . Furthermore, the release of pressure through the backflow tubes 2230 allows for higher belt production speeds. Thus, the overall quality of the belt and the efficiency with which it is produced is improved.

The fibers 10 and resin continue in the pulling direction D_p into the flow L_f zone. The resin material can still travel back through the pressure regulating means 2230 (backflow) if the pressure in this zone is too high. The dashed lines shown by reference number 2 indicate the areas of pressure within the impregnator 2200. In the stabilizing zone L_s the core impregnator 2200 is no longer tapered and the pressure stabilizes so that the load carrier 70 is stable for entering the pultrusion die (see Fig. 3). No backflow of resin occurs in this zone. In the stabilizing zone, the shape of the load carrier 70 and thereby the shape of the belt 100 is preferably

determined. The load carrier 70 having the desired fiber volume fraction V_F exits the impregnator 2200 at the point of exit E2. The desired fiber volume fraction V_F can be an even distribution of fibers 10 arranged equally over the cross-section of the load carrier 70; or be such that a higher fiber volume fraction V_f is present in the center of the load carrier 70; or be such that varying fiber volume fractions V_f exist at various positions throughout the load carrier 70 (shown in Figs 5a to 5c). In this particular example, the preferred fiber volume fraction involves having a higher fiber volume fraction V_F in the center of the load carrier 70 since this is particularly advantageous for belt flexibility.

The rate of resin backflow through the pressure regulating means 2230 can be optionally controlled, thereby also allowing for a degree of control of the resulting fiber volume fraction V_F . Such control can be in the form of, for example, changing the diameter of the tube 2230 at one or more points throughout its length; altering the distance between the tubes 2230 (these are demonstrated more clearly in Figs. 2a and 2b); altering the pressure at the nozzles 2210 supplying the resin material; adjusting the pulling speed of the tractor 2500; utilizing a magnetic field outside the tube 2230 and positioning a complimentary communication means within the tube 2230, or within the resin material itself; using a piezo-electric material, e.g. a piezo wall, as the pressure regulating means. Altering the rate of resin backflow can affect the spacing between the fibers 10 and thereby their location in the cross-section of the load carrier. A higher flow rate will push more fibers towards the center of the cross section and give a higher spacing in the outer areas of the cross section whereas a lower flow rate will give a smaller spacing in the outer areas. The spacing between fibers can also affect the bending properties of the resulting composite elevator belt 100. Thus, it is very advantageous to be able to control the rate of resin back flow.

Fig 2a shows another perspective of the core impregnator 2200 according to the invention and as described in fig. 1. It comprises a point of entry E1, a point of exit E2, a plurality of openings 2210 and a plurality of pressure regulating means 2230 positioned throughout the central area of the cavity 2220. The pressure regulating means 2230 is in the form of tubes which lie in the longitudinal direction of the impregnator 2200 and are spaced laterally across the cavity 2220 (arrow A). Fig. 2b shows an exploded view of the tubes as depicted by arrow A. The tubes 2230 each have a diameter D and are spaced at a distance B from each other. Both the distance of the spacing B and the diameter D can be varied according to the desired fiber volume fraction V_F distribution. It is also envisaged that the spacing B between each tube 2230 may be the same or different. It is also envisaged that the diameter D of one tube 2230 may be the same as or

different to the diameter of other tubes 2230. All variations are ultimately determined by the desired fiber volume fraction V_F .

Fig 3 illustrates a manufacturing apparatus 2000 for making the composite elevator belt 100. Production of the composite elevator belt 100 proceeds in the pulling direction D_P through the components of the manufacturing apparatus 2000. The general components of the manufacturing apparatus 2000 include a fiber spool rack 2100, a core impregnator 2200 as described in fig. 1, a pultrusion die 2300, wherein curing 2340 is also preferably carried out, (curing is shown in fig. 2 as a separate step however this is merely for illustration purposes) a jacket extruder 2400, a tractor 2500, and a spooler 2600. Each of these components of the manufacturing apparatus 2000 will first be individually described, followed by a description of a process for making the composite elevator belt 100 using the manufacturing apparatus 2000. The fiber spool rack 2100 includes one or more spools 2110 on which the fibers 10 are wound. Each fiber 10 of the composite elevator belt 100 may be associated with one of the spools 2110. The one or more spools 2110 may be free-spinning such that a tension force applied to free ends of the fibers 10 causes the fibers 10 to be unwound from the one or more spools 2110. In some embodiments, the one or more spools 2110 may be motorized to assist in the unwinding of the fibers 10 or to apply a defined tension force of the fibers. The core impregnator 2200 is the impregnator already described in fig. 1. It is configured to pre-form a core layer 20 comprising at least one load carrier 70 having a desired fiber volume fraction V_F .

The pultrusion die 2300 is configured to finalize the encasing of the fibers 10 with the core layer 20 and optionally to apply a first and second plurality of teeth (not shown) to the core layer 20. The pultrusion die 2300 includes a housing (not shown) and defining one or more resin chambers (not shown). Both ends of the housing (not shown) along the pulling direction D_P have openings to allow the partially formed composite elevator belt 100 to be pulled through the housing. The pultrusion die 2300 further includes a central heating element (not shown) configured to heat the fibers 10, the core layer 20 within the housing. In some embodiments, the pultrusion die may further include an entry heating element (not shown) and/or exit heating element (not shown) to finely adjust the temperature of the partially formed composite elevator belt 100 entering and/or exiting the housing. Material is supplied to the resin chambers of pultrusion die 2300 via injection openings (not shown) in the housing. In some embodiments, the central heating element may include one or more induction coils (not shown) configured to generate eddy currents in the fibers 10, which may be electrically conductive, according to well-known principles of induction heating. Heating of the fibers 10 causes the partially-formed

composite elevator belt 100 to be heated from the inside out, thereby reducing the occurrence of air bubbles as the core layer 20 cures. In some embodiments, the core layer 20 material may include conductive additives also capable of being heated by the induction coils. Other embodiments of the central heating element may utilize heating devices other than induction coils. Similarly, the entry heating element and/or exit heating element may include induction coils or other heating devices.

The central heating element, entry heating element, exit heating element, and cooling chambers (not shown) are configured to work in conjunction to finely control the temperature of the partially-formed composite elevator belt 100 throughout the formation of the core layer 20 comprising at least one load carrier 70. As such, the pultrusion die 2300 permits a wider variety of materials to be used in production of the composite elevator belt 100 than is possible utilizing conventional pultrusion processes. In some embodiments, the core layer 20 may be formed of fast curing materials, allowing the overall production speed of the composite elevator belt 100 to be increased relative to conventional pultrusion processes.

The jacket extruder 2400 is configured to form a jacket layer (not shown) of the composite elevator belt 100. The jacket extruder 2400 includes at least one extruder head (not shown) for depositing the material that forms the jacket layer. The jacket extruder 2400 is the final component that performs a shaping or forming operation to the partially formed composite elevator belt 100. Thus, the composite elevator belt 100 exits the jacket extruder 2400 in a finished state having all of the desired structural features. The jacket extruder 2400 has openings at both ends along the pulling direction D_P to allow the partially formed composite elevator belt 100 to enter the jacket extruder 2400 and the finished composite elevator belt 100 to exit the jacket extruder 2400.

The tractor 2500 applies a pulling force to pull the composite elevator belt 100 through the preceding components of the manufacturing apparatus 2000. The pulling force of the tractor 2500 is imparted to the composite elevator belt 100 by one or more driven rollers 2510 configured to frictionally engage the finished composite elevator belt 100 exiting the jacket extruder 2400. The driven rollers 2510 may be rotated by a motor to govern the speed of the manufacturing process.

The spooler 2600 is configured to wind the finished composite elevator belt 100 into a spool for packaging. The spooler includes a driven axle (not shown) configured to wind the composite

elevator belt 100 into a spool at the same rate at which the tractor 2500 pulls the composite elevator belt 100.

Having described the individual components of the manufacturing apparatus 2000, further reference is now made to Fig. 4, which is a step diagram 3000 of a process for producing the composite elevator belt 100 using the manufacturing apparatus 2000 described above.

Generally, the method includes using the tractor 2500 to pull the fibers 10 through the core impregnator 2200, the pultrusion die 2300, and the jacket extruder 2400 to form the finished composite elevator belt 100. At step 3100, the tractor 2500 unwinds the fibers 10 from the spools 2110 of the fiber spool rack 2100. As noted above, the spools 2110 may be motorized or equipped with a brake to provide a constant pre-tension in the fiber strands 10 to enhance the quality of the finished composite elevator belt 100 and to prevent compression forces in the fibers 10 due to unequal cooling during the curing of the manufacturing process.

At step 3200, the fibers 10 are pulled by the tractor 2500 into the core impregnator 2200, where the fibers 10 are coated with the resin material forming the core layer 20 comprising at least one load carrier 70 having a desired fiber volume fraction V_F . At step 3300, the partially-formed composite elevator belt 100, i.e., the core layer 20 comprising the at least one load carrier 70 having a desired fiber volume fraction V_F is pulled by the tractor 2500 into the pultrusion die 2300. The incoming fibers 10 can be heated by the entry heating element (not shown) to a predetermined temperature for optimal curing control.

At step 3400, the partially-formed composite elevator belt 100 is pulled by the tractor 2500 into the jacket extruder 2400. Additionally, the core layer 20, if not fully cured already, finishes its curing process. At step 3500, the finished composite elevator belt 100 is wound onto the spooler 2600 via the driven axle (not shown). The driven axle may be calibrated to wind the composite elevator belt 100 onto the spooler 2600 at the same rate at which the composite elevator belt 100 is pulled by the tractor 2500 in order to prevent the occurrence of slack in the composite elevator belt 100. The composite elevator belt 100 is wound onto the spooler 2600 until the desired length of the composite elevator belt 100 has been attained. At that point, the spool of the composite elevator belt 100 may be removed from the spooler 2600. As may be appreciated by those skilled in the art, the composite elevator belt 100 may be produced to a theoretically infinite length limited only by the supply of the raw materials for the strands 10, core layer 20, and jacket.

Steps 3100-3500 may be performed concurrently with one another as the composite elevator belt 100 is continuously drawn through the manufacturing apparatus 2000. That is, as a first portion of fibers 10 are being drawn off the spools 2110, a second portion of fibers 10 are being treated in the core impregnator 2200 and a third portion of fibers 10 are being treated in the jacket extruder 2400. It should be understood that the first, second, and third portions of the partially-formed composite elevator belt 100 referred to above are not discrete, but rather are continuously changing as the partially-formed composite elevator belt 100 is drawn through the manufacturing apparatus 2000.

In other embodiments of the method for making the composite elevator belt 100, one or more of steps 3100-3500 may be performed as discrete operations rather than as a continuous process. For example, steps 3100-3300 may be performed to unwind the fibers 10 from the fiber spool rack 2100 and form the core layer 20 comprising at least one load carrier 70. The load carrier may then be wound onto a temporary storage spool, and steps 3400-3500 may be performed separately. It is to be understood that this embodiment is merely exemplary, and those skilled in the art will appreciate that any individual step or combination of steps 3100-3500 may be performed as a discrete process distinct from the remaining steps 3100-3500.

Figs. 5a to 5c show three examples of a cross-section composite elevator belt 100 comprising a load carrier 70 wherein each example shows a load carrier 70 having a different fiber volume fraction V_f throughout its cross-section. The belt 100 shown in each of fig 5a, 5b, 5c comprises one load carrier 70 - this is for illustration purposes only. It is envisaged that a composite elevator belt 100 obtained according to the invention comprises one or more load carriers 70. Fig. 5a shows a belt 100 comprising a core layer 20 wherein the core layer 20 comprises a load carrier 70 surrounded by resin material 3. The load carrier 70 comprises fibers 10 and has a fiber volume fraction V_f such that the fibers 10 are arranged equally over the cross-section of the load carrier 70.

Fig. 5b shows a belt 100 comprising a core layer 20 wherein the core layer 20 comprises a load carrier 70 surrounded by resin material 3. The load carrier 70 comprises fibers 10 arranged such that a higher fiber volume fraction V_f exists in the center of the load carrier 70. This orientation is particularly desired for belts with improved flexibility.

Fig. 5c shows a belt 100 comprising a core layer 20 wherein the core layer 20 comprises a load carrier 70 surrounded by resin material 3. The load carrier 70 comprises fibers 10 arranged such that varying fiber volume fractions V_f exist at various positions throughout the cross-section of the load carrier 70. This orientation is desired when more than one fiber bundle or cord needs to

be arranged in one resin body, thus providing for a more economical manufacture via only one pultrusion step. Such designs provide a compromise between flexibility and strength.

It should be understood that the figures are not necessarily to scale and present a simplified representation of various features illustrative of the basic principles of the invention. The specific design features of the present invention, for example, dimensions, orientations, locations and shapes; will ultimately be determined by the particular intended application and use environment.

It is to be understood that aspects of the various embodiments described hereinabove may be combined with aspects of other embodiments while still falling within the scope of the present disclosure. Accordingly, the foregoing description is intended to be illustrative rather than restrictive. The assembly of the present disclosure described hereinabove is defined by the claims, and all changes that fall within the meaning and range of equivalency of the claims are to be embraced within their scope.

Reference list

- 1a resin flow
- 1b unwanted resin backflow
- 1c resin backflow
- 1d resin backflow
- 2 pressure field
- 3 resin material
- 10 fiber
- 20 core layer
- 47 injection plane
- 48 backflow plane
- 70 load carrier
- 100 composite elevator belt

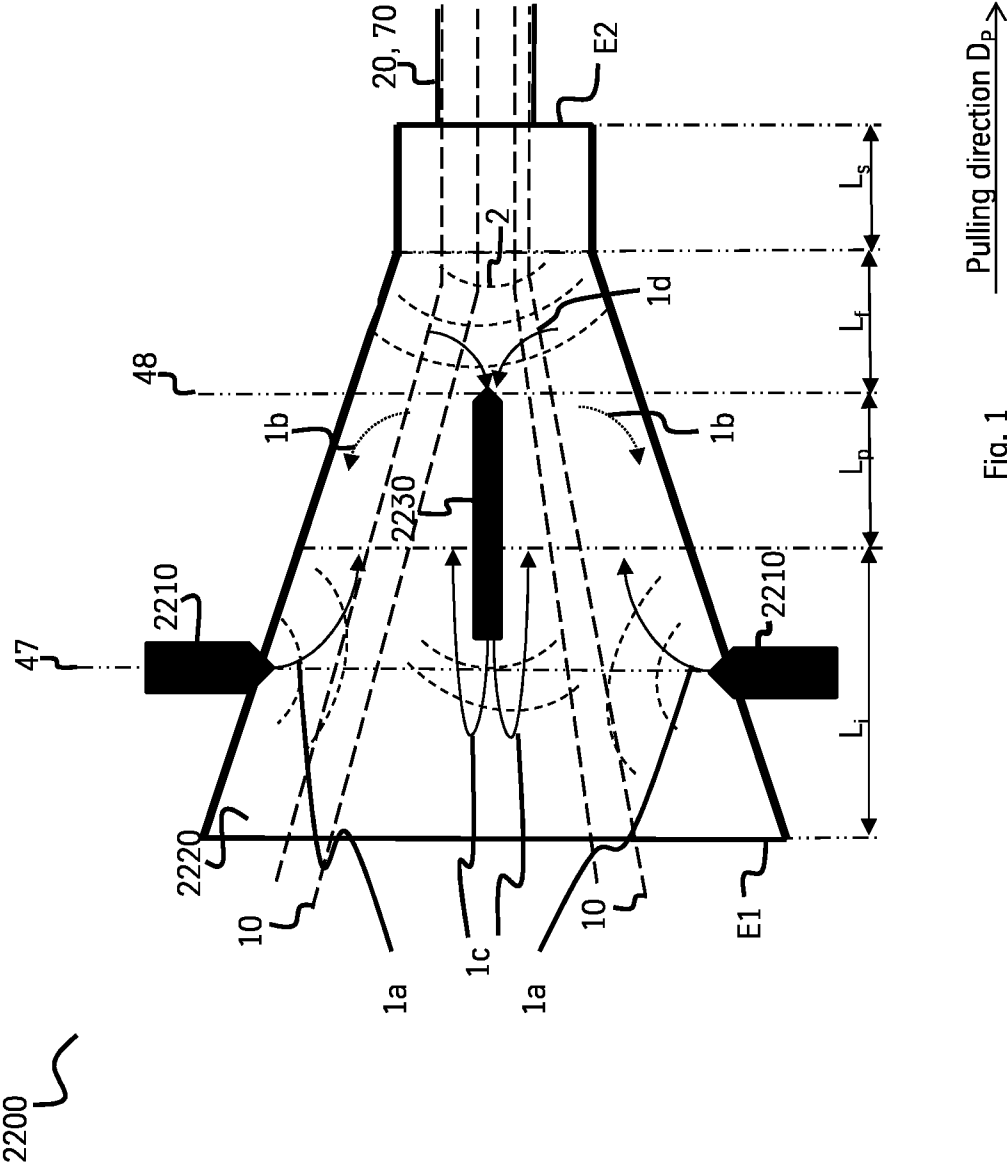
- 2000 manufacturing apparatus
- 2050 fiber arranger
- 2100 fiber spool rack
- 2110 spools
- 2200 core impregnator
- 2210 opening
- 2220 cavity
- 2230 resin backflow tube
- 2300 pultrusion die
- 2340 curing
- 2400 extrusion
- 2500 tractor
- 2510 driven roller
- 2600 spooler

- L_i injection zone
- L_p pressurizing zone
- L_f flow zone
- L_s stabilizing chamber zone

Claims

1. A core impregnator (2200) for use in a process of producing a composite elevator belt, characterized in that it comprises:
 - an inner cavity (2220);
 - at least one opening (2210) for supplying a resin material (20) to the cavity (2220);
 - a point of fiber entry (E1);
 - a point of fiber exit (E2);wherein the point of fiber entry (E1) has a height larger than the point of fiber exit (E2) such that the inner cavity (2220) is tapered.
2. The impregnator (2200) according to claim 1, characterized in that the height difference between the point of fiber entry (E1) and the point of fiber exit (E2) is in a range from 0.1 mm to 1.5 mm.
3. The impregnator (2200) according to claim 1 or claim 2, characterized in that the inner cavity (2220) comprises a tapered angle (β) wherein β lies in a range of 0.01 to 2 degrees.
4. The impregnator (2200) according to claim 3 characterized in that it further comprises at least one pressure regulating means (2230).
5. The impregnator (2200) according to claim 4, characterized in that the at least one pressure regulating means (2230) is located in the cavity (2220).
6. The impregnator (2200) according to any of the preceding claims, characterized in that it comprises a plurality of zones (L_i , L_p , L_f , L_s) wherein said zones include an injection zone (L_i); a pressurizing zone (L_p); a flow zone (L_f) and a stabilizing zone (L_s).
7. The impregnator (2200) according to any of claims 4 to 6, characterized in that the at least one pressure regulating means (2230) is positioned within the injection zone (L_i) and the pressurizing zone (L_p).

8. The impregnator (2200) according to claims 6 to 7, characterized in that the pressure within the injection zone (L_i) is lower than the pressure within the pressurizing zone (L_p) and the flow zone (L_f).
9. The impregnator (2200) according to any of the preceding claims, characterized in that it is adapted to withstand pressures in a range of 0.1- 3 MPa.
10. A process for producing a composite elevator belt (100) comprising the steps of:
 - a) providing a manufacturing apparatus (2000) comprising
 - a fiber spool rack (2100) comprising a plurality of spools (2110) wherein each spool (2110) comprises a fiber (10);
 - a fiber arranger (2050) for arranging the fibers before they are contacted with a resin material (20);
 - a core impregnator (2200) according to any of claims 1 to 9;
 - b) unwinding a plurality of fibers (10) from the fiber spool rack (2100);
 - c) supplying the fibers (10) to the impregnator (2210);
 - d) introducing a resin material (3) to the cavity (2220) of the impregnator (2200) to coat the fibers (10) to provide at least one load carrier (70).
11. The process according to claim 10 further comprising the steps of:
 - g) further treating the at least one load carrier (70) to obtain the composite belt (100);
 - h) collecting the composite belt (100) on a spooler (2600).



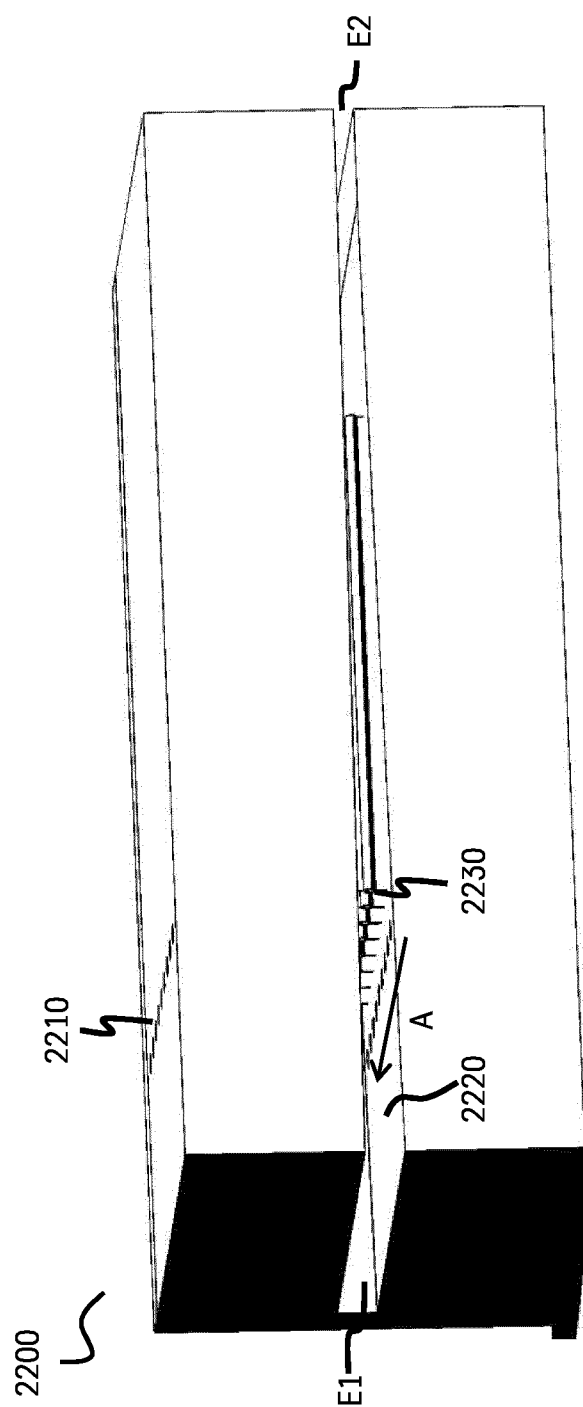


Fig. 2a

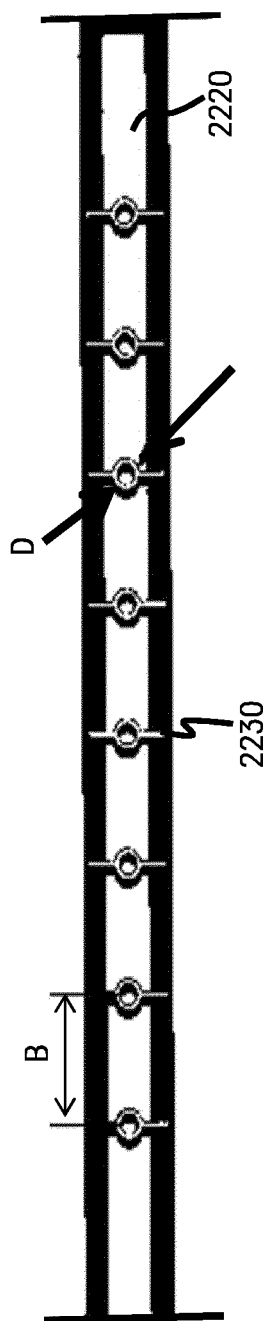


Fig. 2b

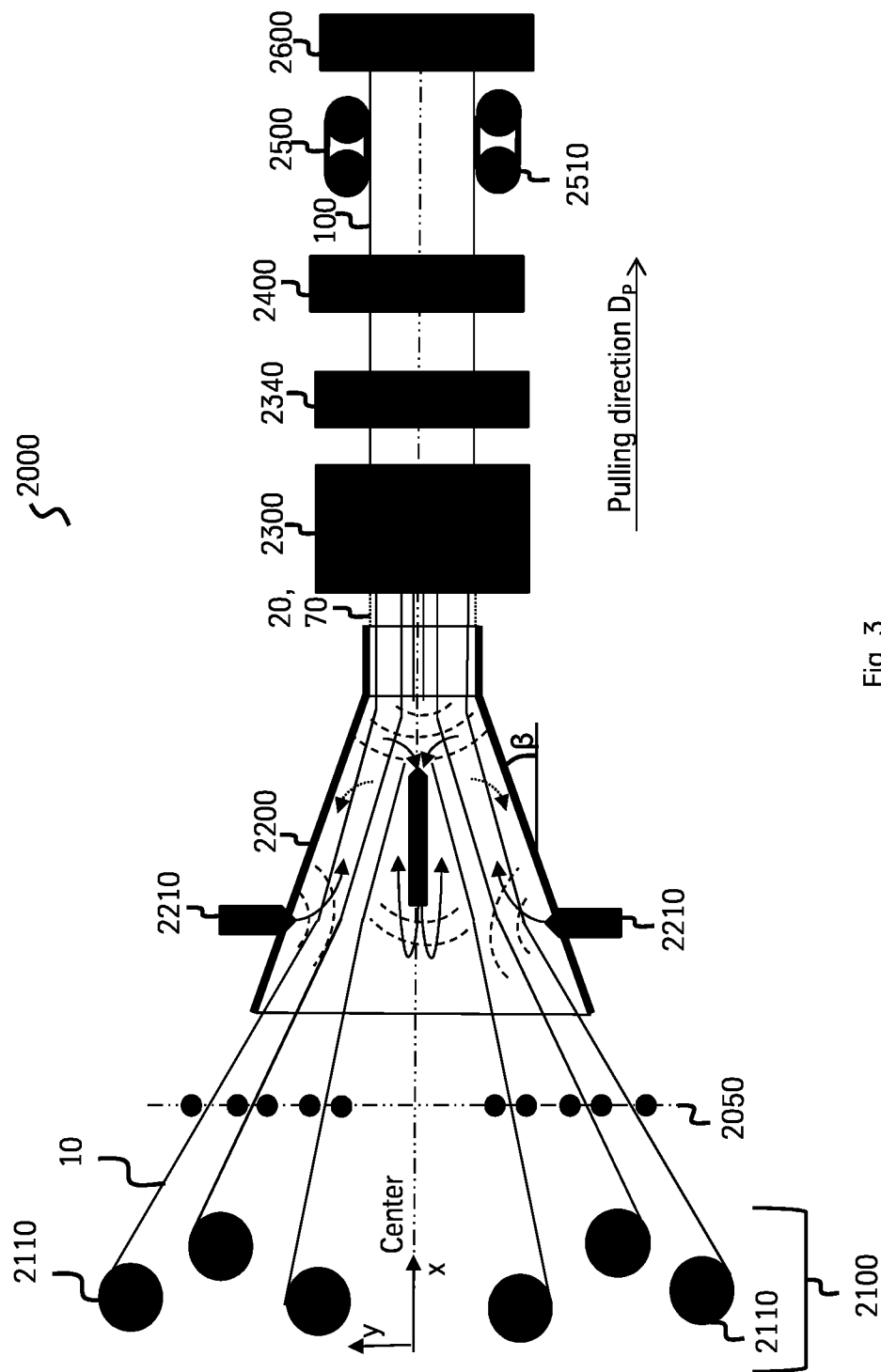


Fig. 3

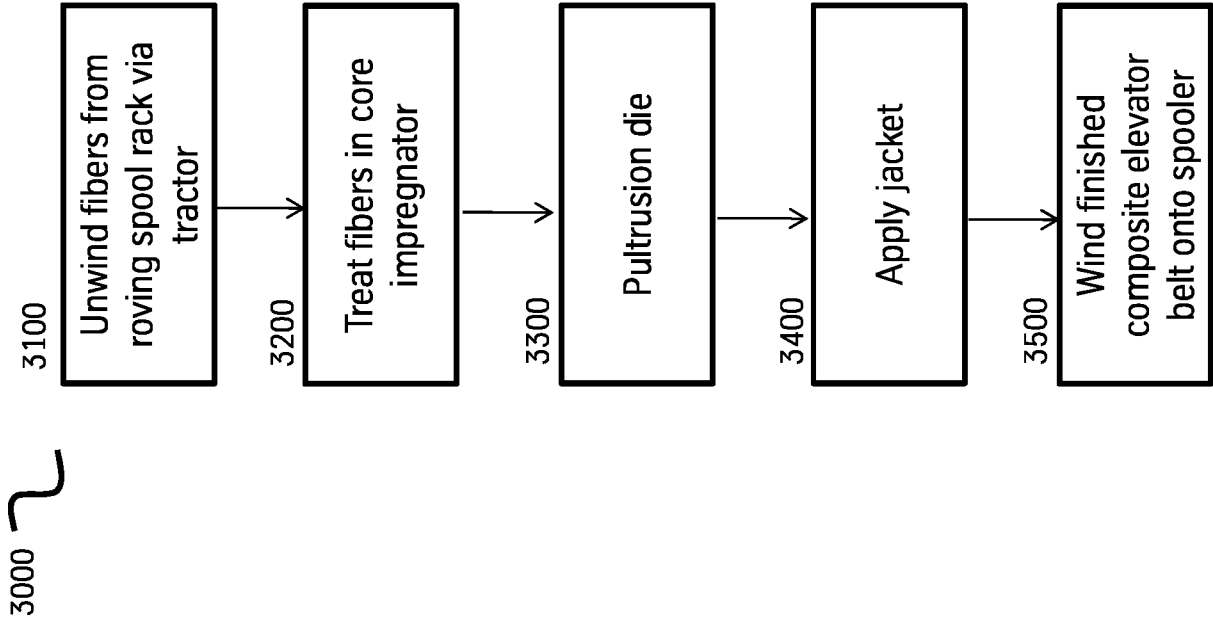


Fig. 4

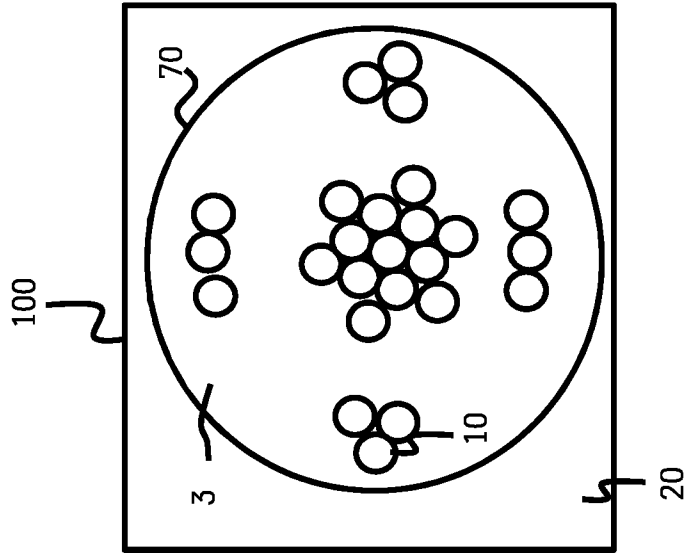


Fig. 5c

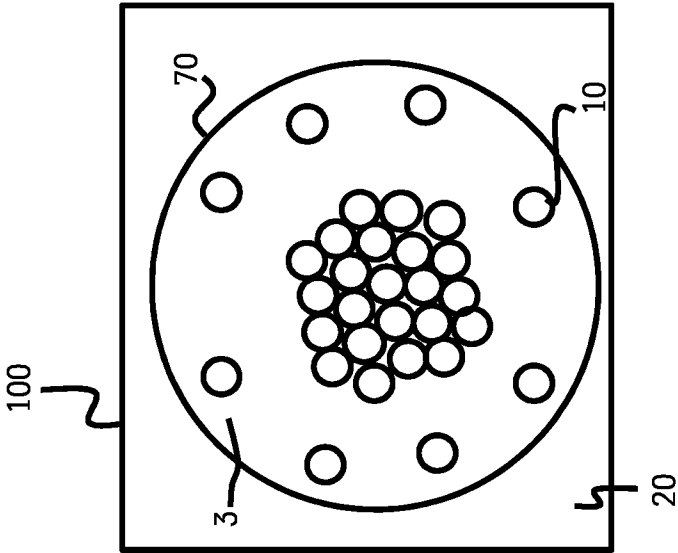


Fig. 5b

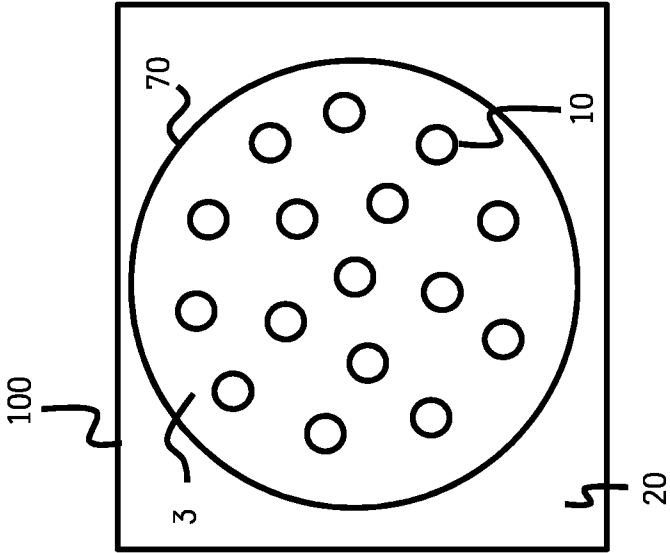


Fig. 5a

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/058306

A. CLASSIFICATION OF SUBJECT MATTER

INV. B29C70/52 B66B7/06 D07B1/06 B29D29/00 B29B15/12
D07B1/16 B29C48/154 B29C48/34

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)

B29C B66B D07B B29D B29B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	abstract; figures	2-5,7-9
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	column 6, line 66 - column 7, line 14; figure 11	
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	column 3, line 35 - line 45; figures 10-13	
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☒ 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

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Date of the actual completion of the international search

11 December 2019

Date of mailing of the international search report

18/12/2019

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/058306

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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International application No

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