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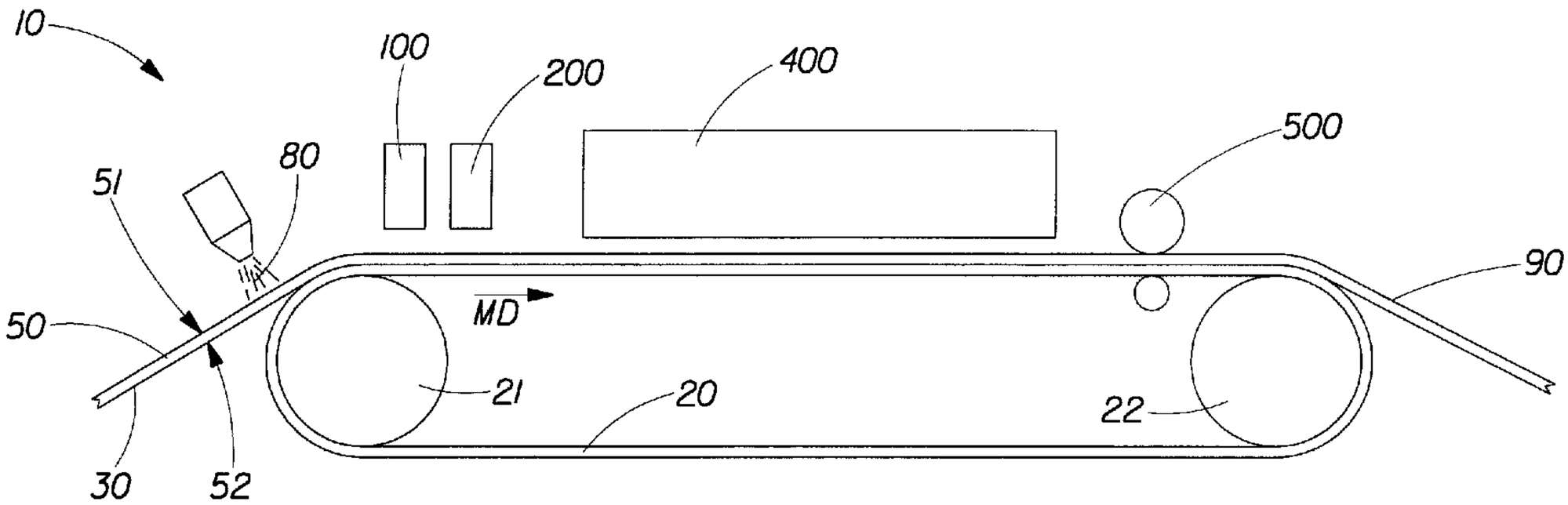
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(54) Titre : PROCEDE ET APPAREIL DE FABRICATION D'UNE TOILE DE MACHINE A PAPIER PAR EXTRUSION
(54) Title: PROCESS AND APPARATUS FOR MAKING PAPERMAKING BELT USING EXTRUSION



(57) Abrégé/Abstract:
A papermaking belt (90) comprises a reinforcing element (50) and a resinous framework (300) joined together. The resinous framework (300) is formed by a plurality of resinous beads (110) which mutually contact or cross-over. Super-knuckles (160) extending outwardly from the reinforcing element (50) are formed at points of contact. A preferred continuous process for making the belt comprises extruding, in a pre-selected pattern, a plurality of beads (110) of a resinous material onto the forming surface thereby forming the resinous framework (300) thereon, joining the resinous framework (300) and the reinforcing element (50) together, and then solidifying the resinous framework (300). The resinous material may comprise at least two chemically-active materials capable of cross-linking upon contact.

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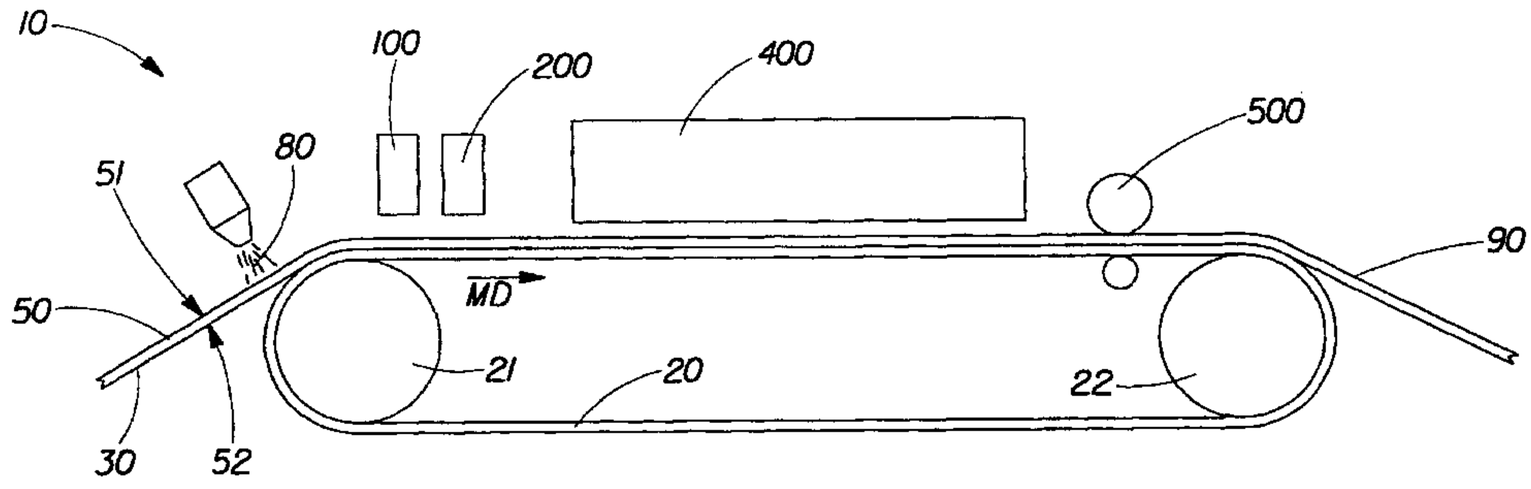
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(54) Title: PROCESS AND APPARATUS FOR MAKING PAPERMAKING BELT USING EXTRUSION



(57) Abstract: A papermaking belt (90) comprises a reinforcing element (50) and a resinous framework (300) joined together. The resinous framework (300) is formed by a plurality of resinous beads (110) which mutually contact or cross-over. Super-knuckles (160) extending outwardly from the reinforcing element (50) are formed at points of contact. A preferred continuous process for making the belt comprises extruding, in a pre-selected pattern, a plurality of beads (110) of a resinous material onto the forming surface thereby forming the resinous framework (300) thereon, joining the resinous framework (300) and the reinforcing element (50) together, and then solidifying the resinous framework (300). The resinous material may comprise at least two chemically-active materials capable of cross-linking upon contact.

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PROCESS AND APPARATUS FOR MAKING PAPERMAKING BELT USING EXTRUSION

FIELD OF THE INVENTION

The present invention generally relates to papermaking belts useful in papermaking machines for making strong, soft, absorbent paper products. More particularly, the invention relates to papermaking belts comprising a resinous framework and a reinforcing element joined thereto.

BACKGROUND OF THE INVENTION

Generally, a papermaking process includes several steps. Typically, an aqueous slurry of papermaking fibers is formed into an embryonic web on a foraminous member, such, for example, as a Fourdrinier wire. After the initial forming of the paper web on the Fourdrinier wire, or forming wires, the paper web is carried through a drying process or processes on another piece of papermaking clothing in the form of endless belt which is often different from the Fourdrinier wire or forming wires. This other clothing is commonly referred to as a drying fabric or belt. While the web is on the drying belt, the drying or dewatering process can involve vacuum dewatering, drying by blowing heated air through the web, a mechanical processing, or a combination thereof.

In through-air-drying processes developed and commercialized by the present assignee, the drying fabric may comprise a so-called deflection member having a macroscopically monoplanar, continuous, and preferably patterned and non-random network surface which defines a plurality of discrete, isolated from one another deflection conduits. Alternatively, the deflection member may comprise a plurality of discrete protuberances isolated from one another by a substantially continuous deflection conduit,

or be semi-continuous. The embryonic web is associated with the deflection member. During the papermaking process, the papermaking fibers in the web are deflected into the deflection conduits and water is removed from the web through the deflection conduits. The web then is dried and can be foreshortened, by, for example, creping. Deflection of the fibers into the deflection conduits of the papermaking belt can be induced by, for example, the application of differential fluid pressure to the embryonic paper web. One preferred method of applying differential pressure is exposing the web to a fluid pressure differential through the drying fabric comprising the deflection member.

Through-air-dried paper webs may be made according to any commonly assigned U.S. Patents: No. 4,529,480 issued to Trokhan on July 16, 1985; No. 4,637,859 issued to Trokhan on Jan. 20, 1987; No. 5,364,504, issued to Smurkoski et al. on Nov. 15, 1994; No. 5,259, 664, issued to Trokhan et al. on June 25, 1996; and No. 5, 679,222, issued to Rasch et al. on Oct. 21, 1997.

Generally, a method of making the deflection member comprises applying a coating of liquid photosensitive resin to a surface of a foraminous element, controlling the thickness of the coating to a pre-selected value, exposing the coating of the liquid photosensitive resin to light in an activating wave-length through a mask, thereby preventing or reducing curing of selected portions of the photosensitive resin. Then the uncured portions of the photosensitive resin are typically washed away by showers. Several commonly assigned U.S. Patents disclose papermaking belts and methods of making the belts: 4,514,345, issued April 30, 1985 to Johnson et al.; 4,528,239, issued July 9, 1985 to Trokhan; 5,098,522, issued March 24, 1992; 5,260,171, issued Nov. 9, 1993 to Smurkoski et al.; 5,275,700, issued Jan. 4, 1994 to Trokhan; 5,328,565, issued July 12, 1994 to Rasch et al.; 5,334,289, issued Aug. 2, 1994 to Trokhan et al.; 5,431,786, issued July 11, 1995 to Rasch et al.; 5,496,624, issued March 5, 1996 to Stelljes, Jr. et al.; 5,500,277, issued March 19, 1996 to Trokhan et al.; 5,514,523, issued May

7, 1996 to Trokhan et al.; 5,554,467, issued Sept. 10, 1996, to Trokhan et al.; 5,566,724, issued Oct. 25, 1996 to Trokhan et al.; 5,624,790, issued April 29, 1997 to Trokhan et al.; 5,628,876 issued May 13, 1997 to Ayers et al.; 5,679,222 issued Oct. 21, 1997 to Rasch et al.; and 5,714,041 issued Feb. 3, 1998 to Ayers et al.

U.S. Patent No. 4,111,634 (Limbach et al.) discloses an apparatus for affixing to a papermaking felt a plurality of beads comprising means for supporting a papermaking felt having a working surface and means for applying beads of plastic backing. The beads extend away from the working surface and have top portions which are spaced from each other along said working surface to form channels for liquid flow.

A search for improved methods and products has continued. Now, it is believed that the deflection member may be made by at least several other methods. The present invention provides a novel process and an apparatus for making a papermaking belt by extruding a fluid resinous material onto the reinforcing element according to a desired predetermined pattern and then solidifying the patterned resinous material. The present invention also provides a process and an apparatus that significantly reduce the amount of the resinous material required to construct the papermaking belt comprising a reinforcing element and a patterned resinous framework.

These and other aspects of the present invention will be more readily apparent when considered in reference to the following description, in conjunction with the accompanying drawings.

SUMMARY OF THE INVENTION

A papermaking belt that can be made by a process and an apparatus of the present invention comprises a reinforcing element and a patterned resinous framework joined thereto. The reinforcing element has a first side and an opposite second side. Preferably, but not necessarily, the reinforcing element comprises a fluid-permeable element, such as, for

example, a woven fabric or a screen having a plurality of open areas therethrough. The reinforcing element may also comprise a felt, as for example disclosed in commonly assigned US patents 5,629,052 and 5,674,663. The resinous framework has a top side and a bottom side, the top and bottom sides corresponding to the first and second sides of the reinforcing element, respectively. The resinous framework may have a substantially continuous pattern, a discrete pattern, or a semi-continuous pattern.

A process for making a papermaking belt includes the following steps: providing a reinforcing element; providing an extrudable resinous material; providing at least a first extrusion die; supplying the resinous material into the extrusion die and extruding the resinous material onto the reinforcing element such that the resinous material and the reinforcing element join together, preferably the resinous material forming a pre-selected pattern on the reinforcing element; and solidifying the resinous material joined to the reinforcing element. Alternatively to extruding the resinous material directly onto the reinforcing element, the resinous material can be extruded onto a forming surface, and then be transferred to the reinforcing element.

In its preferred embodiment, the process is continuous and includes a step of continuously moving the reinforcing element or the forming surface in a machine direction at a transport velocity, and a step of continuously moving of the at least first extrusion die relative to the reinforcing element or the forming surface. Preferably, a plurality of extrusion dies is provided, each die being designed to move relative to the reinforcing element according to a pre-determined pattern. Preferably, each of the extrusion dies is structured to extrude a plurality of beads of the resinous material onto a reinforcing element. The resinous beads extruded onto the reinforcing element may have general orientation in the machine direction, or in the direction substantially orthogonal to the

machine direction including any direction which forms an acute angle with the machine direction. In the latter instance, the combined movement of the reinforcing element (or the forming surface) and the extrusion die or dies preferably produces a resulting velocity vector having a machine-directional component and a cross-machine-directional component. The movement of the reinforcing element (or the forming surface) and the movement of the extrusion dies is designed to mutually cooperate such that the resinous material extruded upon the reinforcing element forms a pre-selected, preferably repeating, pattern. The beads may have a waving configuration, or be straight. Also, the beads may have differential height.

The extrusion dies may be designed to move in a direction substantially orthogonal to the machine direction. In one embodiment of the preferred continuous process, at least two extrusion dies move reciprocally in the direction orthogonal to the machine direction. Depending on a specific pre-selected pattern of the resinous framework, the extrusion die or dies may span substantially the entire width of the reinforcing element, or – alternatively – any portion of the width.

In some embodiments, the extrusion die or dies may have a complex movement, for example, a first reciprocal movement in the direction orthogonal to the machine direction and a second reciprocal movement in the machine direction. An amplitude of the first reciprocal movement is preferably greater than the amplitude of the second reciprocal movement. Then, the resulting pattern of the resinous material extruded onto the reinforcing element comprises a plurality of resinous beads having a waving, or sinusoidal (or oscillating) configuration.

In the most preferred embodiment, the forming surface (or the reinforcing element) is continuously traveling in the machine direction, while the extrusion dies reciprocally move in the cross-machine direction.

In one embodiment, a first plurality of the beads and a second plurality of the beads are extruded onto the forming surface or the reinforcing element in such manner that the first and second pluralities of the beads interconnect when disposed on the forming surface or the reinforcing element, thereby forming the substantially continuous resinous framework. The beads may cross-over, thereby forming "super-knuckles" extending outwardly from the reinforcing element. The super-knuckles, then, can be forced, under pressure, into the reinforcing element such that the reinforcing element and the super-knuckles join together. The rest of the resinous framework may remain not attached to the reinforcing element, thus beneficially providing the belt having a sufficient "skewability" of the reinforcing element relative to the resinous framework. In such embodiment, the resinous framework is securely joined to the reinforcing element while is also partially movable relative to the reinforcing structure.

The present invention contemplates the use of at least two different resinous material, chemically active relative one another. Then, when the first plurality of resinous beads comprising a first resinous material and a second plurality of resinous beads comprising a second resinous material interconnect (by crossing-over or otherwise) in points of contact when disposed on the reinforcing element or the forming surface, the first resinous material and the second resinous material mutually cross-link at the points of contact.

The step of solidifying the resinous framework joined to the reinforcing structure can be performed by any means known in the art, depending on the nature of the resinous framework. For example, the resinous framework comprising a photosensitive resin can be cured with UV radiation, while thermosetting resins are typically cured by temperature.

The process of the present invention may further include a step of controlling a thickness of the resinous framework to at least one pre-selected value. This could be done by calendering the reinforcing element in combination with the resinous framework, sanding at least one side of the composite, cutting the reinforcing structure with a knife or laser beam, or by any other means known in the art.

The present invention also discloses an apparatus for making the belt, the apparatus comprising a forming surface, a means for moving the forming surface in the machine direction, at least one extrusion die structured to move relative to the forming surface, as discussed above, and a means for causing the resinous framework and the reinforcing element to join together. The apparatus can also comprise a means of controlling the thickness of the resinous framework.

One embodiment of the belt of the present invention comprises at least a first plurality of resinous beads having a first thickness, and a second plurality of resinous beads having a second thickness, wherein the first and second pluralities of the resinous beads at least partially overlap at points of contact thereby forming super-knuckles therein, the super-knuckles having a third thickness greater than either one of the first thickness and the second thickness. The first thickness may be different from the second thickness if so desired. The deflection conduits are disposed intermediate the points of contact. Preferably, the super-knuckles are distributed throughout the reinforcing element in a pre-selected pattern, and more preferably, the patterned resinous framework has a substantially continuous pattern. Alternatively, the patterned resinous framework may have a semi-continuous pattern, or a pattern also comprising a third plurality of discrete protuberances outwardly extending from the reinforcing element.

Preferably, the resinous beads comprise a material selected from the group consisting of epoxies, silicones, urethanes, polystyrenes, polyolefins, polysulfides, nylons, butadienes, photopolymers, and any combination thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic side elevational view of one embodiment of a continuous process and an apparatus of the present invention.

FIG. 2 is a schematic side elevational view of another embodiment of a continuous process and an apparatus of the present invention, comprising a support band.

FIG. 3 is a partial cross-sectional view of a fragment 3 of FIG. 2.

FIG. 4 is a schematic plan view showing an embodiment of the process and apparatus of the present invention.

FIG. 5 is a schematic plan view similar to that shown in FIG. 3 and showing another embodiment of the process and apparatus of the present invention.

FIGs. 6-8 schematically show in progress one of the principal embodiments of the process of the present invention.

FIG.6A is a schematic representation of a resulting velocity vector having a machine-directional velocity component and a cross-machine-directional component.

FIG. 9 is a schematic plan view of one exemplary embodiment of the papermaking belt comprising a resinous framework having a semi-continuous pattern.

FIG. 10 is a schematic plan view of another exemplary embodiment of the papermaking belt comprising a resinous framework having a continuous pattern and a pattern comprising a plurality of discrete protuberances.

FIG. 11 is a schematic plan view of another exemplary embodiment of the papermaking belt comprising a resinous framework having a continuous pattern.

FIG. 12 is a schematic plan view of another exemplary embodiment of the papermaking belt comprising a resinous framework having a continuous pattern.

FIG. 13 is a partial cross-sectional view of a fragment 13 of FIG. 2, showing overlapping resinous beads forming super-knuckles.

FIG. 14 is a schematic side elevational view of another embodiment of a continuous process and an apparatus of the present invention, comprising a calendering device.

FIG. 15 is a partial cross-sectional view of a fragment 15 of FIG. 14.

FIG. 16 is a partial cross-sectional view of a fragment 16 of FIG. 14.

FIG. 17 is a schematic side elevational view of another embodiment of a continuous process and an apparatus of the present invention, the apparatus comprising a forming surface separate from a reinforcing element.

FIG. 18 is a partial cross-sectional view of a fragment 18 of **FIG. 17**.

DETAILED DESCRIPTION OF THE INVENTION

Papermaking Belt

A representative papermaking belt , or clothing, also known as a "molding template," which can be made in accordance with the present invention is schematically shown in **FIGs**. **4**, **5**, and **9-13**. As used herein, the term "papermaking belt," or simply "belt," refers to a substantially macroscopically-monoplanar structure designed to support, and preferably carry, a web thereon during at least one stage of a papermaking process. Typically, modern industrial-scale processes utilize endless papermaking belts, but it is to be understood that the present invention may be used for making discrete portions of the belt or stationary, as well as rotary, plates which may be used for making web handsheets, rotating drums, etc.

As **FIG**. **13** shows, the belt **90** has a web-contacting side **91** and a backside **92** opposite to the web-contacting side **91**. The papermaking belt **90** is said to be macroscopically-monoplanar because when a portion of the belt **90** is placed into a planar configuration, the web-side **91**, viewed

as a whole, is essentially in one plane. It is said to be "essentially" monoplanar to recognize the fact that deviations from absolute planarity are tolerable, while not preferred, so long as these deviations are not substantial enough to adversely affect the performance of the belt **90** for the purposes of a particular papermaking process. On a microscopic level, however, the belt **90** is non-planar. In accordance with the present invention, the belt **90** has a plurality of super-knuckles **160** as will be explained below.

The papermaking belt **90** which can be made in accordance with the present invention generally comprises two primarily elements: a framework **300** made of a flowable and extrudable polymeric resinous material, and a reinforcing element, or reinforcing element, **50**. The reinforcing element **50** and the resinous framework **300** are joined together. According to the present invention, the reinforcing element **50** may be partially connected, or joined (**FIGs**. **16** and **18**) to the resinous framework **300**, i. e., only portions of the resinous framework **300** are connected, or joined, to the reinforcing element **50**, thus providing a high degree of flexibility between the reinforcing element **50** and the resinous framework **300**, the benefits of which are explained in greater detail below.

The reinforcing element **50** has a first side **51** and a second side **52** opposite to the first side **51** (**FIGs**. **3**, **13**, **15**, and **16**). The first side **51** may contact papermaking fibers during the papermaking process, while the second side **52** typically contacts the papermaking equipment, such as, for example, a vacuum pickup shoe and a multi-slot vacuum box (both not shown).

The reinforcing element **50** can take any number of different forms. It can comprise a woven element such as for example, a screen, a net, etc., or a non-woven element, such as, for example, a band, a plate, etc. In one

preferred embodiment, the reinforcing element **50** comprises a woven element formed by a plurality of interwoven yarns, as shown in **FIGs. 3, 9, 11, 12, 13, 15,** and **16**. More particularly, the woven reinforcing element **50** may comprise a foraminous woven element, such as disclosed in commonly-assigned U.S. Patent No. 5,334,289, issued in the name of Trokhan et al., on August 2, 1994. The reinforcing element **50** comprising a woven element may be formed by one or several layers of interwoven yarns, the layers being substantially parallel to each other and interconnected in a contacting face-to-face relationship. Reference is made to commonly-assigned U.S. Patent No. 5,679,222, issued to Rasch et al. on October 21, 1997; commonly assigned U.S. Patent 5,496,624, issued on March 5, 1996 in the names of Stelljes, Jr. et al.; and commonly assigned patent application Serial No. 08/696,712 filed in the name of Boutilier on August 14, 1996 and entitled "Papermaking Belt Having Bilaterally Alternating Tie Yarns." The papermaking belt **90** may also be made using the reinforcing element **50** comprising a felt as set forth in a commonly assigned Patent Application Serial No. 08/391,372, filed February 15, 1995, in the name of Trokhan et al. and entitled "Method of Applying a Curable Resin to Substrate for Use in Papermaking."

The reinforcing element **50** of the belt **90** strengthens the resinous framework **300** and preferably has a suitable projected area into which the papermaking fibers can deflect under pressure during the papermaking process. According to the present invention, the reinforcing element **50** is preferably fluid-permeable. As used herein, the term "fluid-permeable" refers, in the context of the reinforcing element **50**, to a condition of the reinforcing element **50**, which condition allows fluids, such as water and

air, to pass through the reinforcing element **50** in at least one direction. As one skilled in the art will readily recognize, the belts comprising a fluid-permeable reinforcing elements are typically used in through-air-dry processes of making a paper web.

The reinforcing element **50** is joined, at least partially, to the resinous framework **300**. The resinous framework **300** comprises a solidified resinous material **300a** or **300b** (**FIG. 14**), i. e., the resinous framework **300** is a solid phase of the fluid resinous material. In that sense, the terms "resinous material" and the “resinous framework” may be used interchangeably where appropriate in the context of the present description. In accordance with the present invention, the resinous framework **300** is formed by a plurality of resinous beads that have been extruded with at least one extrusion die (designated in several drawings as **100** or **200**) and then solidified. The resinous beads define deflection conduits **350** therebetween, as shown in **FIGs. 9-12**.

The resinous framework **300** has a top side **301** and a bottom side **302** opposite to the top side **301** (**FIGs. 9**, **10**, **13**, and **16**). During the papermaking process, the top side **301** of the framework **300** contacts the papermaking fibers, and thus defines the pattern of the paper web being produced. The bottom side **302** of the framework **300** may, in some embodiments (**FIG. 16**), contact the papermaking equipment, in which embodiments the bottom side **52** of the framework **50a** and the second side **42** of the reinforcing element **40** may be disposed in the same macro-plane. Alternatively, a distance **Z** may be formed between the bottom side **302** of the framework **300** and the second side **52** of the reinforcing element, as shown in **FIG. 3**.

Another embodiment (not shown) of the framework **300** may comprise the bottom side **302** having a network of passageways that provide

backside surface texture irregularities, as described in commonly-assigned U.S. Patent 5,275,700 issued on January 4, 1994 to Trokhan. The two latter embodiments of the framework **300** -- one having the distance between the bottom side **302** of the framework **300** and the second side **52** of the reinforcing element **50**, and the other having the backside texture irregularities -- beneficially provide leakage between the bottom side **302** of the framework **300** and a surface of the papermaking equipment. The leakage reduces a sudden application of the vacuum pressure to the paper web during the papermaking process, thereby mitigating a phenomenon known as pinholing.

The papermaking belt used to make structured papers is very expensive to produce. As a result of high costs associated with the production of the belts, it is important to develop designs that on the one hand -- give the desired product performance, and on the other -- run a maximum length of time on a paper machine. A design that is particularly preferred for making structured paper is a composite structure comprising a reinforcing element **50** and a patterned framework **300**, as discussed above. A particularly preferred reinforcing element **50** is a woven fabric shown in **FIGs. 3, 9, 11, 12, 13, and 15-17**. Woven fabrics are preferred as reinforcement because of their strength to weight ratio and because they effectively distribute potentially damaging strains induced by the papermaking process without failing. Woven materials are particularly good at distributing such strains by skewing, that is, distorting in the plane of the weave without going out of plane (ridging). A ridged belt is quickly destroyed as it goes through mechanical nips or wraps around small-diameter rolls; both the mechanical nips and the small-diameter rolls are common on paper machines.

The ability of the woven reinforcing element to skew and hence avoid catastrophic ridging is significantly affected by the way the patterned framework is attached. If the patterned framework is continuous (as, for example, those best shown in **FIGs**. **4**, **5**, and **10-12**) and integrally intermeshed with the woven secondary over its entire projected area, the skewability of the composite is significantly reduced. This is particularly true if the patterned network comprises a high-modulus material. The skewability of the reinforcing element **50** is reduced in these designs because the material of the continuous and interpenetrating patterned framework **300** prevents independent movement of the warp (typically machine-directional) filaments and shute (typically cross-machine-directional) filaments that make up the weave. This causes the normally skewable weave to act more like a rigid homogeneous sheet.

An effective way to attach the patterned framework **300** to the reinforcing element **50**, while maintaining acceptable skewability, is to make attachments periodically rather than continuously, i. e., partially join the reinforcing element **50** and the resinous framework **300**. A preferred means of doing this is to generate a patterned framework **300** that is non-monoplanar on that side which is to be adjoined to the woven reinforcing element **50**. The other side (that side which will ultimately be in contact with the sheet) of the framework **300** may be mono-planar.

A particularly preferred means of doing this is to extrude two periodically intersecting (crossing) beads of a suitable material that form into a preferred pattern. The areas of overlap in the pattern will necessarily be thicker than the non-intersecting regions, i. e. form the "super-knuckles" **160**. The super-knuckles **160** of the patterned framework **300** are then pressed by appropriate means into the woven reinforcing element **50**, thereby creating a periodic jointure between the framework

300 and the reinforcing element **50**. Such a composite will have adequate connectivity between the patterned framework **300** and the reinforcing element **50** and – at the same time – sufficient skewability to avoid catastrophic and costly damage.

In accordance with the present invention, the belt **90** further has a plurality of super-knuckles **160** (**FIGs**. **13** and **16**). The super-knuckles **116** are formed as a result of overlapping of some of the resinous beads. For example, **FIGs**. **11** and **12** show the resinous framework **300** formed by the first plurality **110** of resinous beads and a second plurality **120** of resinous beads. The first and second pluralities **110**, **120** of resinous beads interconnect at points of contact. Specifically, in **FIGs**. **11** and **12**, the resinous beads of the first plurality **110** overlap, or cross-over, the resinous beads of the second plurality **120**, thereby forming the plurality of the super-knuckles **160** at the points of contact **150** and a plurality of the deflection conduits **350** intermediate the points of contact **150**. Preferably, the super-knuckles **160** are distributed throughout the belt **90** in a pre-selected pattern. **FIG**. **13** shows that the beads of the first plurality **110** has a first thickness **A1**, and the beads of the second plurality **120** has a second thickness **A2**. The super-knuckles **160** have a third thickness **A3** which is preferably greater than either one of the first thickness **A1** and the second thickness **A2**. It is to be understood that depending on a particular design of the belt and desired characteristics of the paper, the first thickness **A1** may be equal to the second thickness **A2**, or – alternatively – be different therefrom.

The resinous framework **300** may have a variety of patterns: a continuous pattern, a semi-continuous pattern, a discrete pattern, or any combination thereof. **FIGs**. **10**, **11**, and **13** show the resinous framework having a substantially continuous pattern. As used herein, a pattern is said

to be "substantially" continuous to indicate that minor deviations from absolute continuity may be tolerated, as long as these deviations do not adversely affect the process of the present invention and the performance and desired qualities of the final product -- the papermaking belt **90**. **FIG. 9** shows an example of a semi-continuous pattern of the resinous framework **300**. In a semi-continuous pattern, the continuity of the resinous beads occurs in at least one direction. The commonly assigned U.S. Patent 5,628,876 issued May 13, 1997 in the name of Ayers et al., discloses a semi-continuous pattern of the framework **300**. **FIG. 10** shows an example of the framework **300** also comprising a plurality of discrete protuberances **205** extending outwardly from the reinforcing element. In **FIG. 10** the discontinuous portion, comprising protuberances **205**, of the overall pattern is shown in combination with the continuous portion, comprising overlapping resinous beads.

Process and Apparatus

In one preferred embodiment of the process a first step comprises providing a forming surface **30**. As used herein, the "forming surface" is a surface onto which the resinous material is deposited to form the resinous framework **300**. In the embodiments shown in **FIGs. 1, 2**, and **14**, the forming surface comprises the first surface **51** of the reinforcing element **50**. In the embodiment shown in **FIG. 17**, the forming surface **30** comprises a top surface of an endless band traveling around rolls **21** and **22**. In **FIGs. 1, 2**, and **14**, the forming surface **30** comprising the reinforcing element **50** is supported by an endless support band **20**. In **FIG. 2**, the support band 20 is supported, in turn, by an endless auxiliary

band **30a** (traveling around rolls **31** and **32**) in the zone of forming the resinous framework.

As has been explain above, the reinforcing element **50** is a substrate that may comprise a variety of different forms, such as, for example, a woven fabric, a felt, a screen, a band, etc. A more detailed description of the reinforcing element **50**, particularly one comprising a woven element, is found in commonly-assigned U.S. Patent 5,275,700. Regardless of its specific embodiment, the reinforcing element **50** has a first side **51** and a second side **52**. In the formed papermaking belt **90**, the first side **51** typically faces (and in some embodiments may contact) the papermaking fibers during the papermaking process, while the second side **52** faces (and typically contacts) the papermaking equipment. It should be understood, however, that the belt **90** may have the first side **51** of the reinforcing element **50** facing the papermaking equipment, and the second side **52** of the reinforcing element **50** facing the papermaking fibers, as will be explained below in sufficient detail. As used herein, the first side **51** and the second side **52** of the reinforcing element **50** are consistently referred to by these respective names regardless of incorporation (i. e., prior, during, and after the incorporation) of the reinforcing element **50** into the papermaking belt **90**. A distance between the first side **51** and the second side **52** of the reinforcing element **50** forms a thickness of the reinforcing element, designated herein as "**S**" (**FIGs. 3** and **16**). In the preferred continuous process of the present invention, the forming surface **30** and/or the reinforcing element **50** continuously move in a machine direction, indicated in several figures as "**MD**." The use herein of the term "machine direction" is consistent with the traditional use of the term in papermaking, where this term refers to a direction which is parallel to the flow of the paper web through the papermaking equipment. As used

herein, the "machine direction" is a direction parallel to the flow of the reinforcing element **50** during the process of the present invention. It should be understood that the machine direction is a relative term defined in relation to the movement of the reinforcing element **40** at a particular point of the process. Therefore, the machine direction may (and typically does) change several times during a given process of the present invention. As used herein, a term “cross-machine direction” is a direction perpendicular to the machine direction and parallel to the general plan of the papermaking belt being constructed. The forming surface **30** further has a longitudinal direction and a transverse direction. As used herein, the longitudinal direction is any direction which lies within the range of less than ±45° relative to the machine direction, and the transverse direction is any direction which lies within the range of ±45° relative to the cross-machine direction.

In several embodiments of the preferred continuous process schematically shown in the drawings, the forming surface **30** and/or the reinforcing element **50** move(s) in the machine direction, preferably at a transport velocity. Typically, but not necessarily, the transport velocity is constant. In **FIGs**. **1**, **2**, and **14**, the forming surface **30** comprising the reinforcing element **50** is supported by rolls **21** and **22**. Depending on a specific embodiment of the process, the reinforcing element **50** may be provided in the form of an endless element. Preferably, the reinforcing element **50** is supported by a support for the reinforcing element **20**, which in **FIGs**. **1**, **2**, and **14** is shown in the form of an endless belt **20** traveling around the rolls **21** and **22**. The primary function of the support **20** is to support the reinforcing element **50** in the zone in which the resinous framework is being formed (i. e., intermediate the rolls **21** and **22**), such that the reinforcing element **50** has a sufficiently stable cross-sectional

profile. The support **20** may also have a function of supporting the resinous material being deposited onto the reinforcing element **50** to form the resinous framework **300**. The auxiliary forming surface **30a**, mentioned above, may be used to provide an additional support for the resinous material being deposited onto the reinforcing element **50**.

The next step of the process of the present invention comprises providing at least a first extrudable resinous material **300a**. As used herein, the term "extrudable resinous material" refers to a wide variety of polymeric resins and plastics that can achieve and maintain under certain conditions and/or for a certain period of time, a fluid, or liquid, state such that the resinous material can be sufficiently extruded with an extrusion die onto the forming surface **30** and then solidify to form the framework **300**, as has been explained herein above. The flowable resinous material of the present invention may comprise a material selected from the group consisting of: epoxies, silicones, urethanes, polystyrenes, polyolefines, polysulfides, nylons, butadienes, and any combination thereof.

The examples of the suitable liquid resinous material comprising silicones, include, but are not limited to: “Smooth-Sil 900,” “Smooth-Sil 905,” “Smooth-Sil 910,” and “Smooth-Sil 950.” The examples of the suitable liquid resinous material comprising polyurethanes, include, but are not limited to: “CP-103 Supersoft,” “Formula 54-290 Soft,” “PMC-121/20,” “PL-25,” “PMC-121/30,” “BRUSH-ON 35,” “PMC-121/40,” “PL-40,” “PMC-724,” “PMC-744,” “PMC-121/50,” “BRUSH-ON 50,” “64-2 Clear Flex,” “PMC-726,” “PMC-746,” “A60,” “PMC-770,” “PMC-780,” “PMC-790.” All the above exemplary materials are commercially available from Smooth-On, Inc., Easton, PA, 18042. Other examples of the liquid resinous material include multi-component materials, such as, for example, a two-

component liquid plastic "Smooth-Cast 300," and a liquid rubber compound "Clear Flex 50," both commercially available from Smooth-On, Inc.

Photosensitive resins may also be used as the resinous material. The photosensitive resins are usually polymers that cure, or cross-link, under the influence of radiation, typically ultraviolet (UV) light. References containing more information on liquid photosensitive resins include Green et al., "Photocross-Linkage Resin Systems," J. Macro-Sci. Revs Macro Chem. C21 (2), 187-273 (1981-82); Bayer, "A Review of Ultraviolet Curing Technology", TAPPI Paper Synthetics Conf. Proc., Sept. 25-27, 1978, pp. 167-172; and Schmidle, "Ultraviolet Curable Flexible Coatings", J. of Coated Fabrics, 8, 10-20 (July, 1978). Especially preferred liquid photosensitive resins are included in the Merigraph series of resins made by MacDermid, Inc., of Waterbury, CT.

The examples of thermo-sensitive resins that can comprise the resinous material of the present invention include, but are not limited to: a group of thermoplastic elastomers Hytrel® (such as Hytrel® 4056, Hytrel®7246, and Hytrel®8238); and Nylon Zytel® (such as Zytel®101L, and Zytel®132F), commercially available from DuPont Corporation of Wilmington, DE.

Preferably, the flowable resinous material is provided in a liquid, or fluid, form. The present invention, however, contemplates the use of the flowable resinous material which is provided in a solid form. In the latter instance, an additional step of fluidizing the resinous material is required.

Embodiments of the present invention are contemplated, in which the resinous material comprises a chemically-active components. As used herein, at least two "chemically-active" materials comprise materials which are capable of cross-linking when they contact or are mixed. While some

chemically-active materials may cross-link under ambient conditions, other chemically-active materials require a catalyst to cross-link. One skilled in the art will recognize that the catalyst may comprise a variety of conditions, such as, for example, temperature, pressure, moisture, oxygen, etc., depending on a specific nature of the chemically-active materials being mutually contacted. Prophetically, the examples of chemically-active resinous materials that can be used in the present invention include but are not limited to various epoxy resins, such as, for example, Epoxy System™ 2, 3, 5, 6, and 10, available from Epoxy Systems, Inc. of Jericho, Vermont.

The next step comprises providing at least one extrusion die **100** structured to receive and extrude the resinous material therefrom onto the forming surface **30**. For simplicity, two exemplary extrusion dies are shown in several drawings: a first extrusion die **100** and a second extrusion die **200**. It is to be understood, however, that the term "at least one extrusion die" includes any desired plurality of the extrusion dies. A variety of extrusion dies known in the art can be used in the present invention. The examples of the extrusion dies include but are not limited to those disclosed in the following US patents: 3,959,057, issued to Smith on 5/25/76; 4,050,867, issued to Ferrentino, et al. on 9/27/77; 4,136,132, issued to Poole on 1/23/79; 4,259,048, issued to Miani on 3/31/81; and 5,876,804, issued to Kodama et al. on 3/2/99. The preferred extrusion die is structured to extrude a plurality of resinous beads onto the forming surface **30**.

The next step comprises supplying the first resinous material **300a** into the extrusion die **100** and extruding the resinous material **300a** therefrom onto the forming surface **30**. The extrusion die or dies should preferably provide for the proper conditions (such as, for example,

temperature) to keep the flowable resinous material in a fluid extrudable state. As used herein, the terms "fluid" and “liquid” refer to a condition, state, or phase, of the resinous material, in which condition the resinous material is capable of being extruded and which allows the resinous material to be deposited onto the forming surface **30**. If thermoplastic or thermosetting resins are used as the resinous material, typically a temperature slightly above the melting point of the resinous material is desired to maintain the resin in a fluid extrudable state. The resinous material is considered to be at or above the "melting point" if the resinous material is wholly in the fluid state. One skilled in the art will appreciate that the process of extruding of the resinous material from the extrusion die or dies depends on a specific embodiment of the extrusion die or dies and characteristics of the resinous material.

Preferably, the resinous material is extruded onto the forming surface **30** in a pre-selected pattern. According to the present invention, the pattern may be formed by moving at least one of the forming surface **30** and the extrusion die **100**. In a preferred continuous process, the forming surface is continuously traveling in the machine direction **MD** at a transport velocity. As one skilled in the art will understand, if the extrusion die **100** is stationary (i. e., does not move) the resulting pattern of the resinous material disposed on the forming surface **30** comprises a substantially straight lines (not shown). If, however, the extrusion die or dies move relative to the forming surface **30**, for example in the cross-machine direction **CD**, as shown in **FIGs**. **6-8**, the resulting velocity vector **V** of the combined movement will have a machine-directional component **Vmd**, which is parallel to the machine direction **MD**, and a cross-machine-directional component **Vcd**, which is parallel to the cross-machine direction **CD** (**FIG. 6A**). **FIGs**. **6**, **7**, and **8** schematically show in progress the

process of creating one embodiment of the substantially continuous resinous framework **300.** The first extrusion die **100** and the second extrusion die **200** reciprocally travel in the cross-machine direction **CD** spanning a pre-determined cross-machine-directional distance (shown in **FIGs. 6, 7, 8** as the width of the forming surface **30** formed between the first edge **31** and the second edge **32** thereof), while the forming surface **30** continuously travels in the machine direction **MD**. The resulting pattern of the resinous beads extruded onto the forming surface **30** comprises a plurality of "diagonal" lines disposed at an angle different from 90° relative to the machine direction. As one skilled in the art will readily appreciate, this angle is defined by relative velocities of the forming surface **30** and the extrusion dies **100, 200**. **FIGs. 6, 7,** and **8** schematically show an exemplary extrusion dies **100, 200**, each forming several beads of the resinous material. The beads which are formed by the first extrusion die **100** are indicated by a symbol "**1**" and the beads which are formed by the second extrusion die **200** are indicated by a symbol "**2**". It is to be understood, however, that the number of beads and their cross-sectional shape may be chosen based on specific requirements of the process and the resulting resinous framework **300**. It should also be understood that the beads **1** formed by the first extrusion die **100** need not be disposed mutually adjacent in the final resinous framework **300**, and the beads **2** may be interposed between the beads **1**.

For illustration, in **FIGs. 6, 7**, and **8**, the first and second extrusion dies **100** and **200** are designated with suffix "**a**" in the beginning of the cycle (i. e., "**100a**" and "**200a**" respectively) and with a suffix "**b**" at the end of the cycle (i. e., "**100b**" and "**200b**" respectively). In **FIG. 6**, the first extrusion die **100** begins its movement in the cross-machine direction **CD** from the first edge **31** to the second edge **32** of the forming surface **30**, and

the second extrusion die **200** begins its movement in the cross-machine direction **CD** from the second edge **32** of the forming surface **30**. **FIGs. 6** schematically shows a partially formed pattern of the resinous framework **300** after completion of the first cycle of the process. **FIG. 7** schematically shows the forming surface **30** having a partially formed pattern of the resinous framework **300** and locations of the first and second extrusion dies **100, 200** relative to the partially formed pattern. It should be understood that the designations "the first extrusion die **100**" and "the second extrusion die **200**" are for illustrative purposes only. In **FIGs. 7** and **8** the first and second extrusion dies **100, 200** may be easily visualized as being mutually transposed. **FIG. 8** shows the first and second extrusion dies **100, 200** moving in the opposite directions near completion of the second cycle of the process.

The forming surface **30** may continually travel in the machine direction until the entire pattern of the resinous framework **30** is formed. Alternatively, the movement of the forming surface **30** may be indexed. In the latter embodiment, the pattern of the resinous framework **300** may be formed in several cycles, and the resinous material may be deposited onto the same machine-directional portions of the forming surface in several cycles. For example, the forming surface **30** may be stopped after each cycle for a period of time allowing the extrusion dies to be repositioned, as necessary. Also, a position of the forming surface **30** may be adjusted after each cycle, depending on a particular pattern of the resinous framework **300** being made. It is also possible to vary the direction of the movement of the forming surface **30**; for example, during the first cycle the forming surface **30** is traveling in the machine direction MD as explained herein above (**FIG. 6**), while during the second cycle the forming surface **30** is traveling back, i. e., in a direction opposite to the machine direction.

The latter embodiment of the process is not shown but can be easily visualized (based on **FIGs. 7** and **8**) by one skilled in the art. Between the cycles, the positions of the extrusion dies **100** and **200** can be adjusted as needed.

The extrusion dies **100, 200** may have a complex movement. For example, at least one of the extrusion dies **100, 200**, shown in **FIGs. 6, 7,** and **8**, may reciprocally move in the machine direction **MD** while also moving in the cross-machine direction **CD**. The frequency and amplitude of the machine-directional movement is preferably less than the frequency and amplitude of the cross-machine-directional movement. The resulting pattern of the resinous framework **300** would then comprise a plurality of resinous beads having a wavy configuration. The resinous beads may or may not intersect, depending on a particular pattern of the resinous framework **300**. Two examples of patterns in which the resinous beads intersect are shown in **FIGs. 11** and **12**, in which the resinous beads have the transverse orientation and a wavy configuration. In **FIG. 11**, the adjacent resinous beads **110** have a first transverse orientation (from lower left to upper right). In **FIG. 11**, the beads **110**, while having the same general orientation on a macro-level (i. e., when the resinous framework **300** is viewed as a whole), are not mutually parallel on a micro-level (i., e., when viewed in relation to a single deflection conduit **350**). Such an embodiment may be formed (referring to the process principally shown in **FIGs. 6, 7**, and **8**) by forming first -- the first group of parallel beads **111**, and then -- a second group of parallel beads **112**, the beads **111** and **112** mutually alternating, i. e., each of the beads **112** of the second group being formed between a pair of the beads **111** of the first group, the beads **111** of the first group being non-parallel on a micro-level to the beads **112** of the second group. Based on the process principally shown in **FIGs. 6,**

7, and **8**, one skilled in the art can visualize that the beads **111**, **112** may be formed by the extrusion dies having reciprocal machine-directional movement. In **FIG. 12**, the adjacent resinous beads **110** having a first transverse orientation are parallel on both the macro-level and the micro-level.

FIGs. 4 and **5** show another embodiment of the process. In **FIGs. 4** and **5**, the first and second extrusion dies **100, 200** reciprocally move in cross-machine direction **CD**, while the forming surface **30** is traveling in the machine direction **MD**. The resulting pattern of the resinous framework **300** comprises a plurality of resinous beads generally oriented in the machine direction **MD** and having a wavy (or "oscillating") configuration. Depending on relative velocity and amplitude of the extrusion dies **100, 200** and the velocity of the forming surface **30**, a variety of configurations of the resinous beads may be formed. In both **FIGs. 4** and **5**, the adjacent resinous beads contact one another at points of contact **150**, thereby creating a substantially continuous resinous framework **300**. The resulting resinous framework **300** comprises a plurality of deflection conduits **350** formed between the adjacent resinous beads and the points of contact **150** thereof. In **FIG. 5**, the resinous beads overlap at points of contact **150** thereby forming the super-knuckles **160**, discussed above.

It is to be understood that the embodiments schematically represented in **FIGs. 6, 7, 8** and **11, 12** are mere examples of a vast, and virtually unlimited, variety of possible arrangements of the relative movements of the extrusion die or dies and the forming surface, according to the present invention. Therefore, the examples shown and described herein must be treated not as limitations of the present invention but as principal examples of preferred embodiments thereof. Embodiments in which the resinous beads do not contact, thereby forming a semi-

continuous pattern if the resinous framework **300** are also contemplated in the present invention.

Present invention also contemplates using at least two different chemically-active resinous materials, as defined above. In this instance, during the process, the first extrusion die **100** is extruding the first plurality of the resinous beads comprising the first chemically-active material, and the second extrusion die **200** is extruding the second plurality of the resinous beads comprising the second chemically-active material. The first and second pluralities of the resinous beads contact when disposed on the forming surface **30**. Upon contact, the first chemically-active material comprising the first plurality of the beads and the second chemically-active material comprising the second plurality of the beads cross-link at the points of contact. It is believed that a sufficiently secure connection could thus be formed between the first and second pluralities of the resinous beads.

The next step comprises causing the resinous framework **300** and the reinforcing element **50** to join together. It should be appreciated that the forming surface **30** may or may not be defined by the reinforcing element **50**. In the embodiments of the process shown in **FIGs. 1, 2,** and **14**, the reinforcing element **50** comprises the forming surface **30**. Stated differently, in **FIGs. 1, 2,** and **14**, the forming surface **30** is defined by one of the first side **51** and the second side **52** of the reinforcing element **50**. Alternatively, in the embodiments shown in **FIGs. 17** and **18**, the reinforcing element **50** comprises an element independent from the forming surface **30**. In the latter instance, a surface energy of the forming surface **30** is preferably less than a surface energy of the reinforcing element **50**. Several ways exist of creating a surface energy differential between the forming surface **30** and the reinforcing element **50**. A material

comprising the forming surface **30** may inherently have a relatively low surface energy, or can be treated to lower its surface energy. Alternatively or additionally, the forming surface **30** can be treated with a release agent **60** (**FIG. 17**) prior to the step of depositing the resinous material on the forming surface **30**. Examples of the release agent include but are not limited to: "Ease Release™," "Permarelease™," "Aqualease™," "and Actilease™," available from Smooth-On, Inc. In **FIG. 17**, the release agent **60** is schematically shown as being sprayed onto the forming surface **30** from a source **65**. It is to be understood, however, that the release agent **60** may be also brushed or wiped onto the forming surface **30**, in which instances the source **65** may comprise a brush, a trough, or any other suitable device known in the art.

In the embodiments in which the reinforcing element **50** comprises the forming surface **30**, the step of causing the resinous framework **300** and the reinforcing element **50** to join together may occur almost simultaneously with the step of extruding the resinous material onto the reinforcing element **50**. The fluid resinous material and the reinforcing element **50** may be chosen such that the resinous material is capable of at least partially penetrating the reinforcing element **50** thereby joining thereto upon solidification. One skilled in the art will appreciate that in the latter instance, such properties of the extrudable resinous material as viscosity/fluidity, surface tension, chemical reactivity, temperature, and such qualities of the reinforcing element **30** as microscopic geometry and surface energy are highly relevant.

Alternatively or additionally, the reinforcing element **50** or at least its first surface **51** may be treated with an adhesive material **80** (**FIG. 1**) prior to depositing the resinous material onto the reinforcing element **30**. The suitable adhesive materials include but are not limited to: contact cement,

cyanoacrylate, anaerobic adhesives, such as, for example, omniFIT and SICIMENT, available from Chicago Glue Machine and Henkel Corporation, various melt glues, such as ADVANTA, moisture-curing and UV-curing silicones, epoxies, urethanes, and any combination thereof.

The adhesive **60** may be deposited onto/into the reinforcing element **50** by, for example, spraying (**FIG. 1**), printing with a printing roll (not shown), immersing the reinforcing element **50** into the bath with the adhesive (not shown), or by any other suitable means known in the art.

The step of causing the resinous framework **300** and the reinforcing element **50** to join together may comprise calendering the reinforcing element **50** in combination with the resinous framework **300**, with the calendering device **40** as best shown in **FIG. 18**. In the latter instance, a step is highly preferred comprising continuously moving the forming surface **30** and the reinforcing element **50** at a transport velocity such that at least a portion of the reinforcing element **50** is in a face-to-face relationship with at least a portion of the resinous framework **300** formed on the forming surface **30**. While the resinous framework **300** is still flowable, the portion of the reinforcing element **50** facing the forming surface **30** contacts the resinous framework **300** for a predetermined period of time sufficient for the resinous framework **300** to join to the reinforcing element **30**.

The forming surface **30** can be made using a variety of suitable materials known in the art. The examples include but are not limited to: fluorocarbon polymers, such as, for example, polytetrafluoroethylene (or PTFE, also known as Teflon®); GoreTex® commercially available from W. L. Gore & Associates, Inc. of Newark, DE; microporous materials, commercially available from Millipore Corp. of Bedford, MA; micropore tapes made by 3M Corporation of St. Paul, MN; various sintered

materials, such as, for example, Dynapore® porous stainless steel wire mesh laminates made by Martin Kurtz & Co., Inc. of Mineola, NY; and sintered alloys available from National Sintered Alloys, Inc. of Clinton, CT; and woven metal wire cloths commercially available from Haver & Boecker of Oelde, Germany and Haver Standard India Pvt. Ltd. (HAST) of Bombay, India.

A calendering device **40** may be used to facilitate the step of causing the resinous framework **300** and the reinforcing element **50** to join together, regardless of a specific embodiment of the forming surface **30**. **FIGs. 14** and **17** schematically shows the calendering device **40** comprising three pairs of juxtaposed calendering rolls **41-41a**, **42-42a**, and **43-43a**. This arrangement can beneficially provide for a incrementally-discrete application of a calendering pressure by designing a nip between the rolls **42-42a** smaller than a nip between the rolls **41-41a**, and a nip between the rolls **43-43a** smaller the nip between the rolls **42-42a**.

The embodiment of the resinous framework **300** shown in **FIG. 18** comprises the super-knuckles **160**, as discussed above. **FIG. 18** also shows the embodiment of the process in which the resinous framework **300** and the reinforcing element **50** in contact therewith are impressed together between the rolls **51** and **52** to the extent that allows the reinforcing element **50** only partially join to the resinous framework **300**, i. e., the reinforcing element **50** joins primarily to the super-knuckles **160**. Stated differently, a nip between the calendering rolls **51** and **52** may be chosen such that the reinforcing element **50** and the resinous framework **300** join together by way of the super-knuckles **160** being joined to the reinforcing element **50**. The rest of the resinous framework **300** may or may not be joined to the reinforcing element **50**. The advantages of partial, or periodical, joining are explained above.

One embodiment of the process of the present invention believed to be especially beneficial is schematically shown in **FIGs. 15** and **16**. In **FIG. 16**, a partially-formed resinous framework comprises a plurality of resinous beads **110**, **210** that are disposed on the reinforcing element **50** and cross-over thereon. The super-knuckles **160** are formed at the points of contact **150**. The reinforcing element **50**, comprising a woven element, is supported by the support band **20**, as explained above. When the partially-formed resinous framework in association with the reinforcing element is calendered with the calendering device **40** (**FIG. 14**), the resinous beads **110** are forced, under calendering pressure, into the reinforcing element **50** to the extent sufficient to provide a secure joining between the reinforcing element **50** and the resinous framework. If desired, depending on the relative dimensions of the reinforcing element **50** and the resinous beads, the resinous beads **110** can be forced through the entire thickness of the reinforcing element **50** such that they contact the support band **20**. In **FIG. 16**, only the beads **110** are directly joined to the reinforcing element **50**, while the beads **210** are not. As explained above, this embodiment of the belt **90** is believed to provide the benefit of allowing a high degree of freedom of the resinous framework from the reinforcing element, while providing a secure interconnection therebetween.

The next step comprises solidifying the resinous framework **300** joined to the reinforcing element **50**. As used herein, the term "solidification" and derivations thereof refer to a process of altering a fluid to a solid, or partially solid, state. Typically, solidification involves a phase change, from a liquid phase to a solid phase. The term "curing" refers to a solidification in which cross-linking occurs. For example, photosensitive resins may be cured by UV radiation, as described in commonly assigned

U.S. Patents 5,334,289; 5,275,700; 5,364,504; 5,098,522; 5,674,663; and 5,629,052. The thermo-plastic and thermo-setting resins require a certain temperature for solidification. Preferably, the step of solidification comprises curing of the resinous material.

Pre-solidification of the resinous material may begin as early as immediately after the fluid resinous material has been deposited onto the forming surface **30** to form the resinous framework thereon. A method of solidifying the resinous material depends upon its nature. If a thermoplastic or thermosetting resin is used, solidifying comprises cooling the resinous material. Photopolymer resins may be cured by a process of curing described in commonly assigned U.S. Patents 4,514,345; and 5,275,700, referred to above. The resinous material comprising multi-component resins or plastics may solidify naturally, during a certain predetermined period of time, by virtue of being mixed together. In some embodiments, solidification of the resinous material may begin right after the resinous material has been extruded onto the forming surface **30**. A step of pre-solidification may be required to allow the resinous framework **300** formed on the forming surface **30** to sufficiently retain its shape during the following step of causing the reinforcing element **50** and the resinous framework **300** to join together. As used herein, the "pre-solidification" refers to partial solidification of the resinous material such that the resinous material is capable of sufficiently retaining the desired shape, and yet soft enough to be effectively joined to the reinforcing element **50**. A degree of pre-solidification depends upon the type of the resinous material and its viscosity, relative geometry of the resinous beads and the reinforcing element **50**, the time during which the

step of joining is being performed, and other relevant parameters of the process and the apparatus of the present invention.

According to the present invention, an embodiment is contemplated in which the resinous framework **300** formed on the forming surface **30** pre-solidifies such that the outer surface of the resinous framework **300** solidifies first, while the rest of the resinous material is still in a substantially fluid state. Then, the outer surface of the resinous framework **300**, which is at least partially solidified, functions as a shell for the rest of the resinous framework **300** which is still at least partially fluid. This embodiment may be particularly beneficial in the process using the reinforcing element **50** having void spaces therethrough, such as, for example, a woven reinforcing element schematically shown in **FIGs. 3, 9**, and **11--18**. In this embodiment, when the pressure is applied to the partially-solidified resinous framework **300**, the resinous material is "pushed" through the yarns of at least the first side **51** of the reinforcing element **50**, without prohibitively distorting the shape of the resinous framework **300**, for the partially-solidified "shell" preserves the shape of the resinous framework **300**. Typically, although not necessarily, the resinous framework **300** does not merely attach to the reinforcing element **50**, but "wraps" around structural elements of the reinforcing element **50** (such as, for example, individual yarns in a woven reinforcing element **50**), to adequately lock on them, thereby at least partially encasing some of them. The pressure causes the resinous material to penetrate between the structural elements of the reinforcing element **50**.

As an example, **FIGs. 1, 2, 14,** and **17** schematically show the curing apparatus **400** juxtaposed with the forming surface **30**. Depending on the type of the resinous material, the examples of the curing apparatus **400** include, but are not limited to: a heater for increasing cross-linking

reaction rates or condensing rates for condensing polymers; a cooler for solidifying thermoplastics; various apparatuses providing an infra-red curing radiation, a microwave curing radiation, or a ultra-violet curing radiation; and the like. Commonly assigned patent application, Serial No. 08/799,852, entitled "Apparatus for Generating Parallel Radiation For Curing Photosensitive Resin" filed in the name of Trokhan on February 13, 1997; and commonly assigned patent application, Serial No. 08/858,334, entitled "Apparatus for Generating Controlled Radiation For Curing Photosensitive Resin" filed in the names of Trokhan et al. on February 13, 1997 show several embodiments of the curing apparatus **400** which can be used for solidifying the resinous framework **300** comprising a photosensitive resin. The curing device **400** may also be used for the pre-solidification purposes, as discussed above.

Optionally, a step of controlling the thickness of the belt may be provided in the process of the present invention. The thickness of the resinous framework **300** may be controlled by the calendering device **40** as explained above. The thickness of the belt **90** being made may be controlled to a pre-selected value by controlling the third distance **A3** (**FIG. 13**). Also, the thickness of the belt **90** being made be controlled by controlling the depth of recesses **Z** (**FIG. 3**). Alternatively or additionally, such means may be used as a rotating sanding roll **50** (**FIG. 1**), and/or a planing knife, and/or a laser, or any other means known in the art and suitable for the purpose of controlling the thickness caliper of the belt **90** being made.

The process and the apparatus of the present invention significantly reduces the amount of the flowable resin that is required to be used in constructing the belt **90**, and thus provides an economic benefit. The prior

art's methods of making the belt, using a photosensitive resin and a curing radiation, requires application of a coating of the photosensitive resin to the reinforcing element, curing selected portions of the resinous coating, and then removing (typically, washing out) uncured portions of the resinous coating. The amount of the resin being washed out may be as high as 75% relative to the amount of the entire resinous coating. In the present invention, the exact amount of the resinous material, which is required for the resinous framework **300**, can be formed on the forming surface **30**. Furthermore, the process and the apparatus of the present invention allows one to create virtually unlimited number of patterns of the resinous framework **300**.

WHAT IS CLAIMED IS:

1. A process for making a papermaking belt (90) comprising a reinforcing element (50) and a resinous framework (300) joined thereto, the process comprising the steps of:

(a) providing a forming surface (30) having a longitudinal direction and a transverse direction, and continuously moving the forming surface in a longitudinal direction at a transport velocity;

(b) providing an extrudable resinous material, comprising a material selected from the group consisting of epoxies, silicones, urethanes, polystyrenes, polyolefins, polysulfides, nylons, butadienes, photopolymers, and any combination thereof;

(c) providing at least a first extrusion die (100) structured to extrude the resinous material, supplying the resinous material into at least the first extrusion die (100), and extruding the resinous material therefrom onto the forming surface;

the process *characterized* in that the first extrusion die continuously moves the transverse direction, whereby a combined movement of the forming surface (30) and at least the first extrusion die (100) produces a pre-selected pattern of the resinous framework (300) formed by the first resinous material being deposited onto the forming surface (30) from the first extrusion die (100);

2. The process according to Claim 1, further comprising the steps of causing the resinous framework (300) and the reinforcing element (50) to join together; and solidifying the resinous framework (300) thereby forming the papermaking belt (90).

3. The process according to Claims **1** and **2**, wherein the step of continuously moving the at least first extrusion die (100) relative to the forming surface (30) comprises a reciprocal movement.

4. The process according to Claims **1, 2**, and **3**, wherein in the step (c) the at least first extrusion die (100) is structured to extrude at least a first plurality of resinous beads onto the forming surface (30).

5. The process according to Claims **1, 2, 3**, and **4**, wherein the step (c) further comprises providing a second extrusion die (200) structured to extrude the resinous material onto the forming surface (30) in a pre-selected pattern.

6. The process according to Claims **1, 2, 3, 4**, and **5**, wherein in the step (d) the resinous framework (300) has a substantially continuous pattern.

7. The process according to Claims **1, 2, 3, 4, 5**, and **6**, wherein in the step (a) the forming surface (30) comprises the reinforcing element (50).

8. A process for making a papermaking belt (90) comprising a reinforcing element (30) and a resinous framework (300) joined thereto, the process comprising the steps of:

(a) continuously moving the reinforcing element (50) in a machine direction at a transport velocity, the reinforcing element (50) having a longitudinal direction and a transverse direction;

(b) forming and depositing onto the reinforcing element (50) at least a first plurality of resinous beads comprising a first resinous material, and

(c) causing the reinforcing element (50) and the resinous framework (300) to join together;

the process *characterized* in that the step (b) comprises forming and depositing onto the reinforcing element (50) a second plurality of resinous beads comprising a second resinous material such that the first and second pluralities of the resinous beads interconnect when disposed on the reinforcing element, thereby forming a resinous framework (300) thereon, wherein at least some of the resinous beads at least partially cross over, thereby forming super-knuckles (160) extending outwardly from the reinforcing element (50).

9. The process according to Claim **8**, wherein causing the reinforcing element (50) and the resinous framework (300) to join together is accomplished by forcing the super-knuckles (160) into the reinforcing element (50) under pressure such that the reinforcing element (50) and the super-knuckles (160) join together, preferably by calendering the reinforcing element in combination with the resinous framework associated therewith.

10. The process according to Claims **8** and **9**, further characterized in that the first resinous material and the second resinous material are chemically active relative to one another, and the first and second resinous materials cross-link with one another at the points of contact.

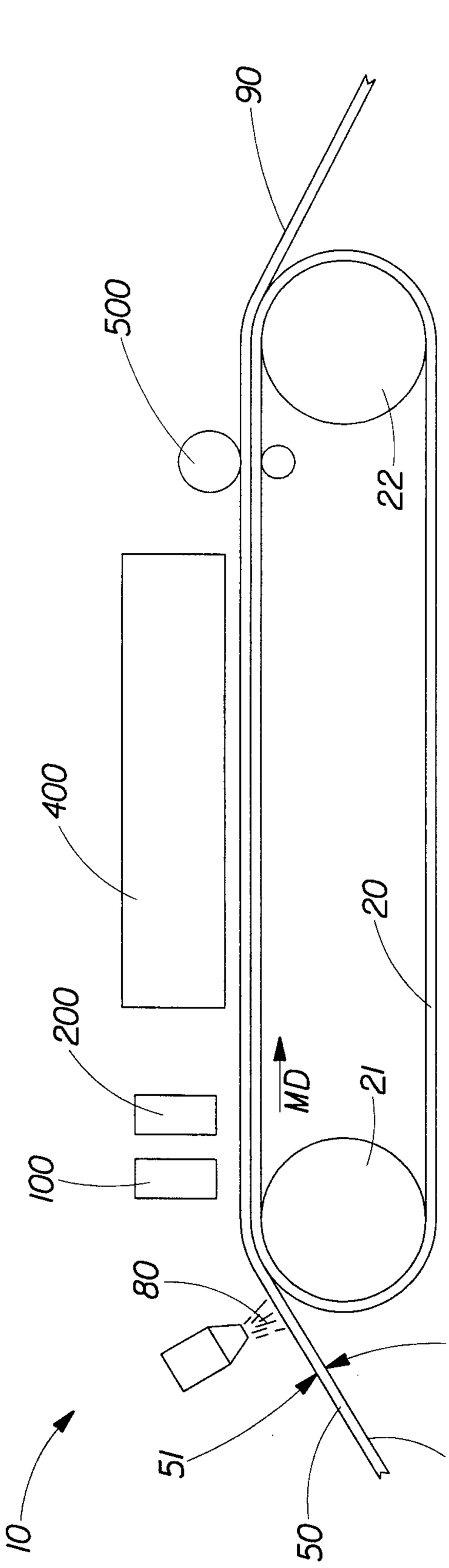

90
500
22
400
200
100
MD
21
20
80
52
51
50
30
10

Fig. 1

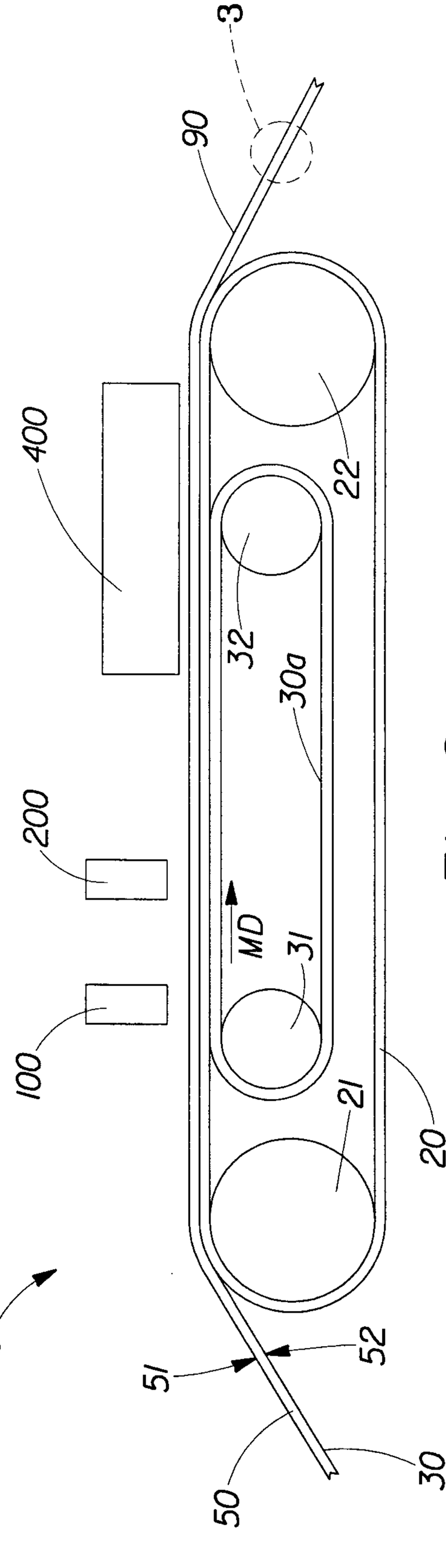

90
22
400
32
30a
200
MD
31
100
21
20
51
52
50
30
10

Fig. 2

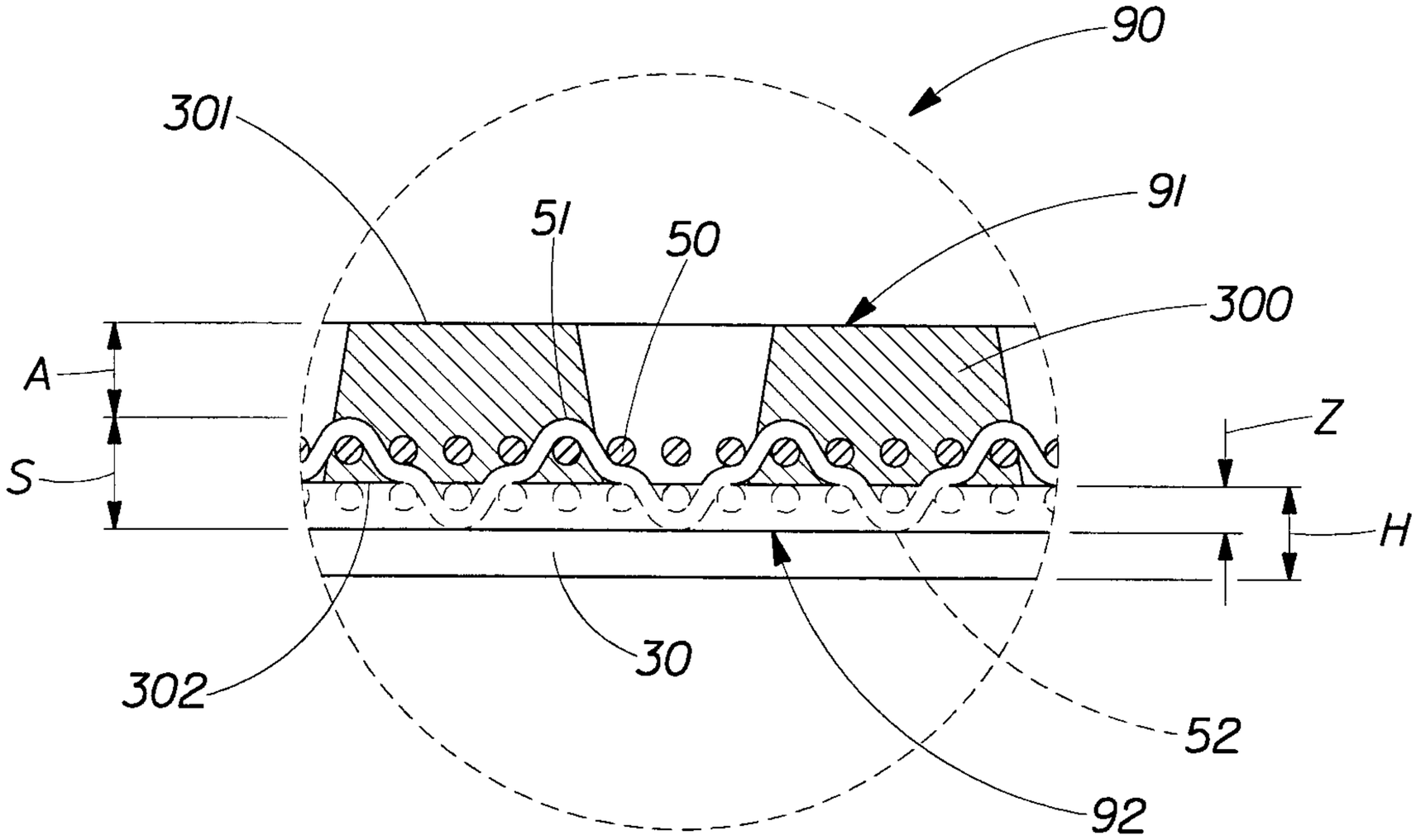


Fig. 3

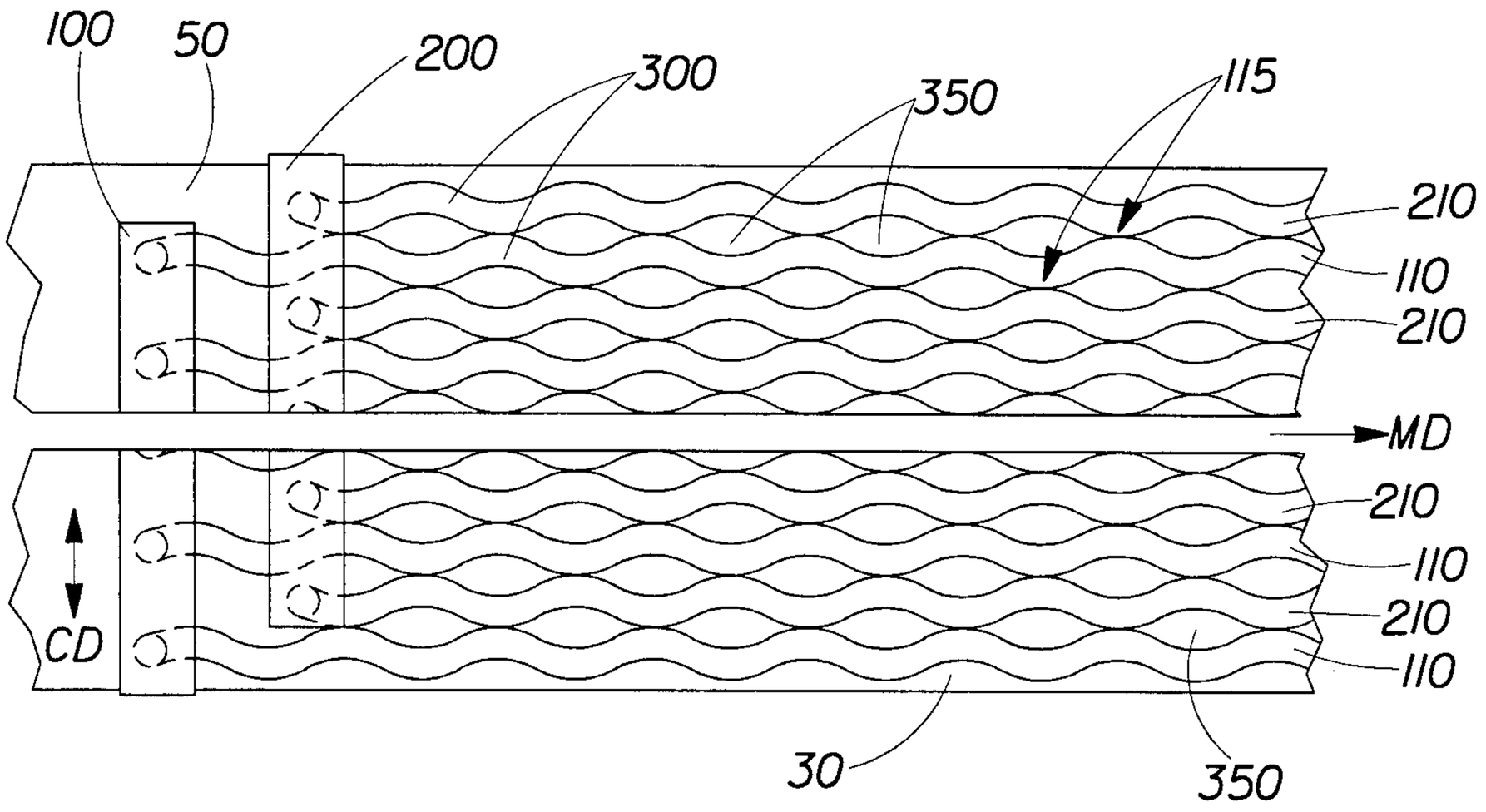

100
50
200
300
350
115
210
110
210
MD
210
110
210
110
CD
30
350

Fig. 4

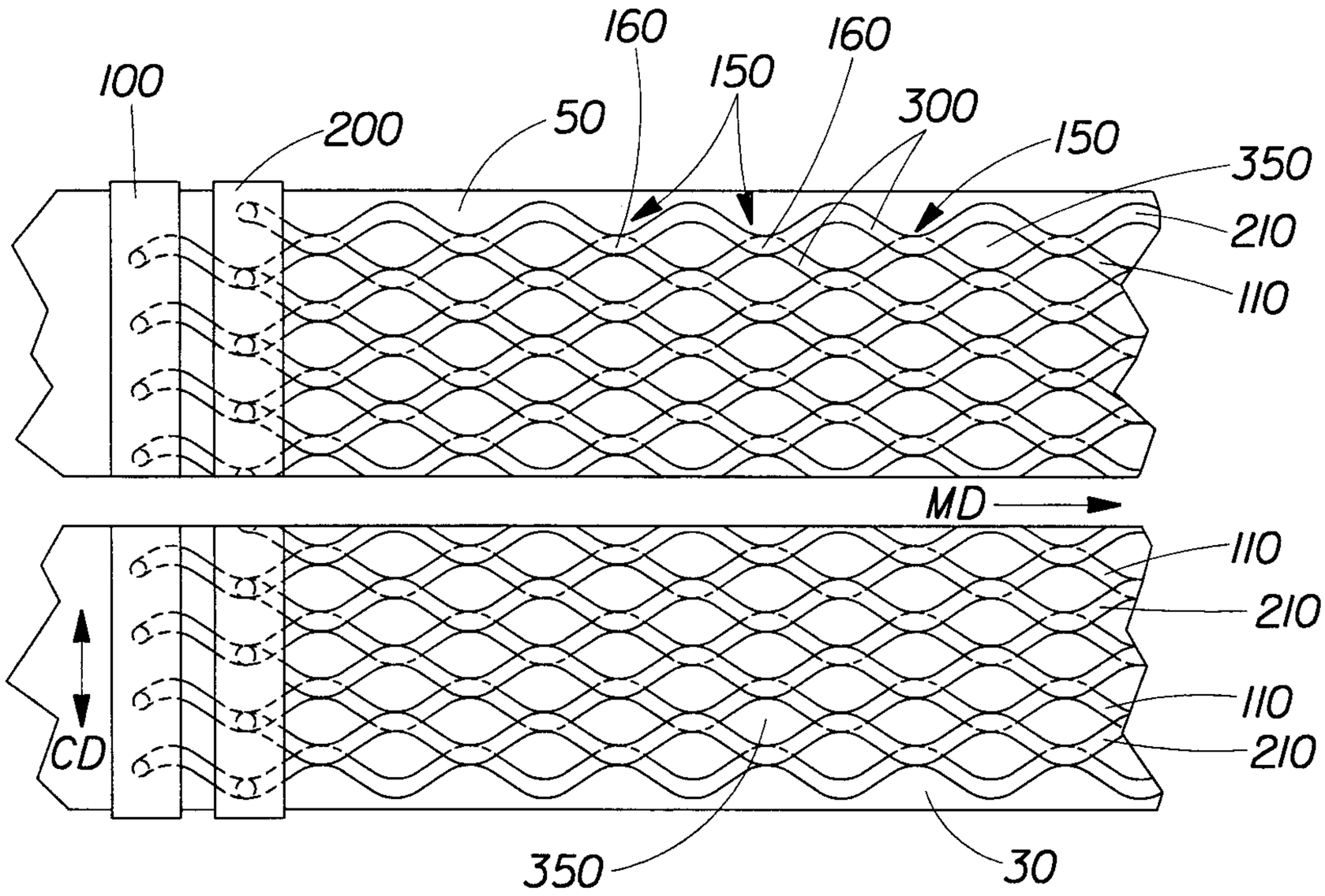

100
200
50
160
150
160
300
150
350
210
110
MD
110
210
110
210
CD
350
30

Fig. 5

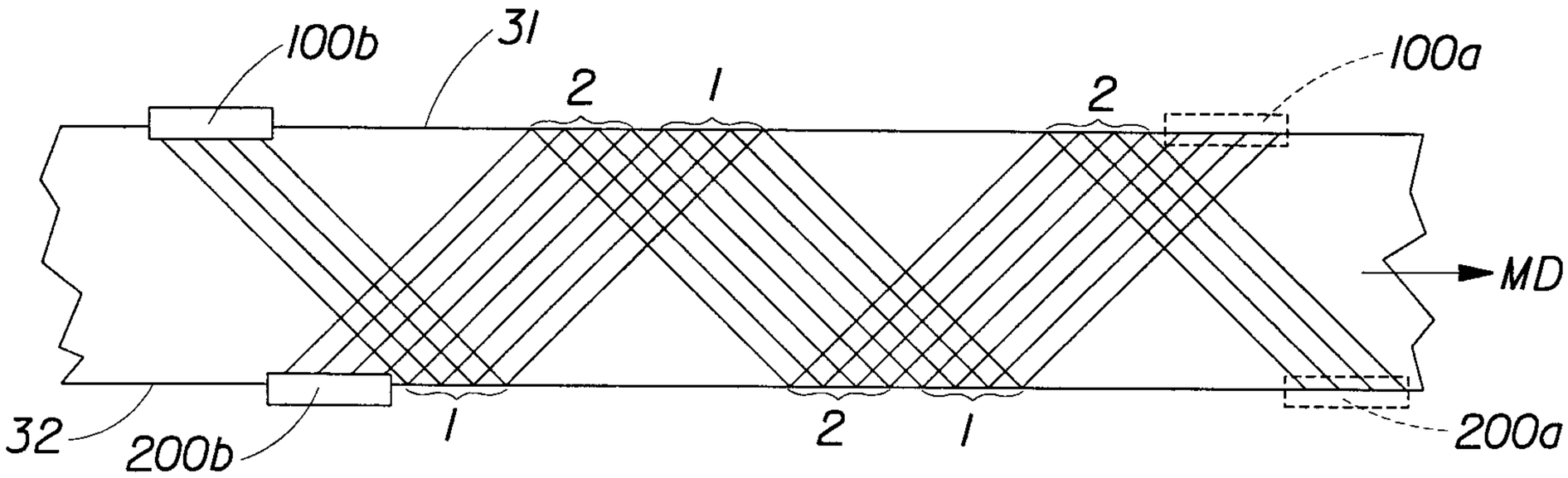


Fig. 6

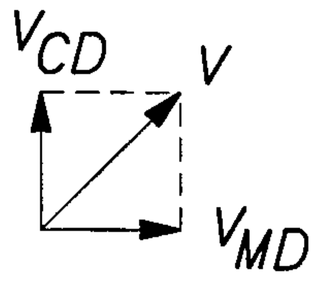


Fig. 6A

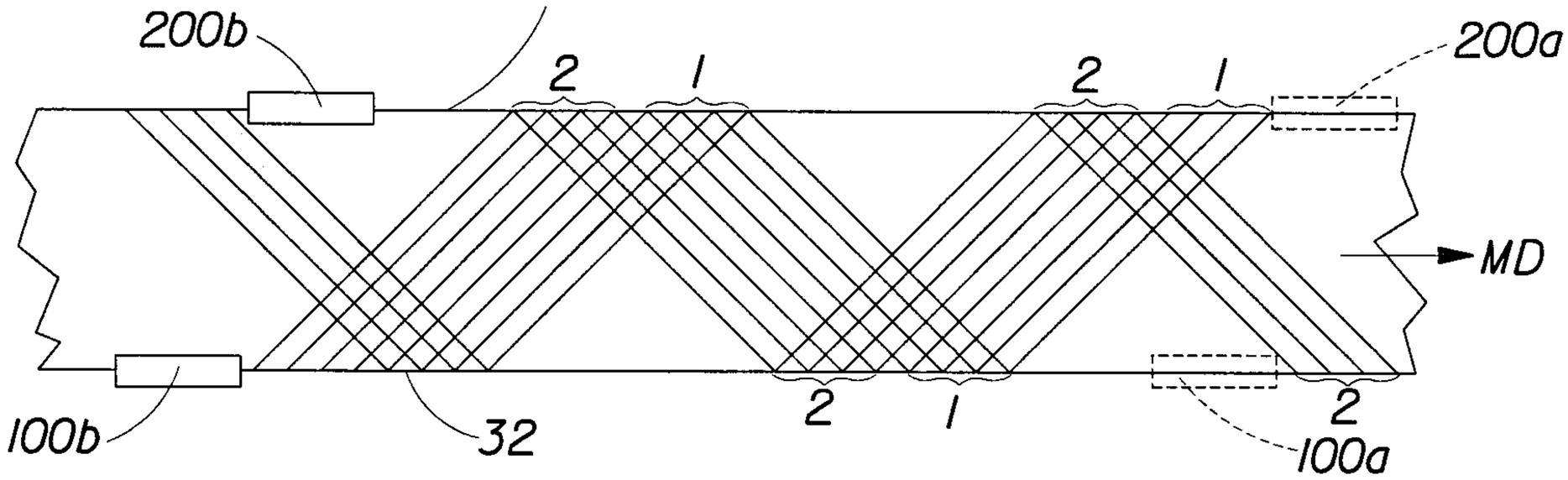


Fig. 7

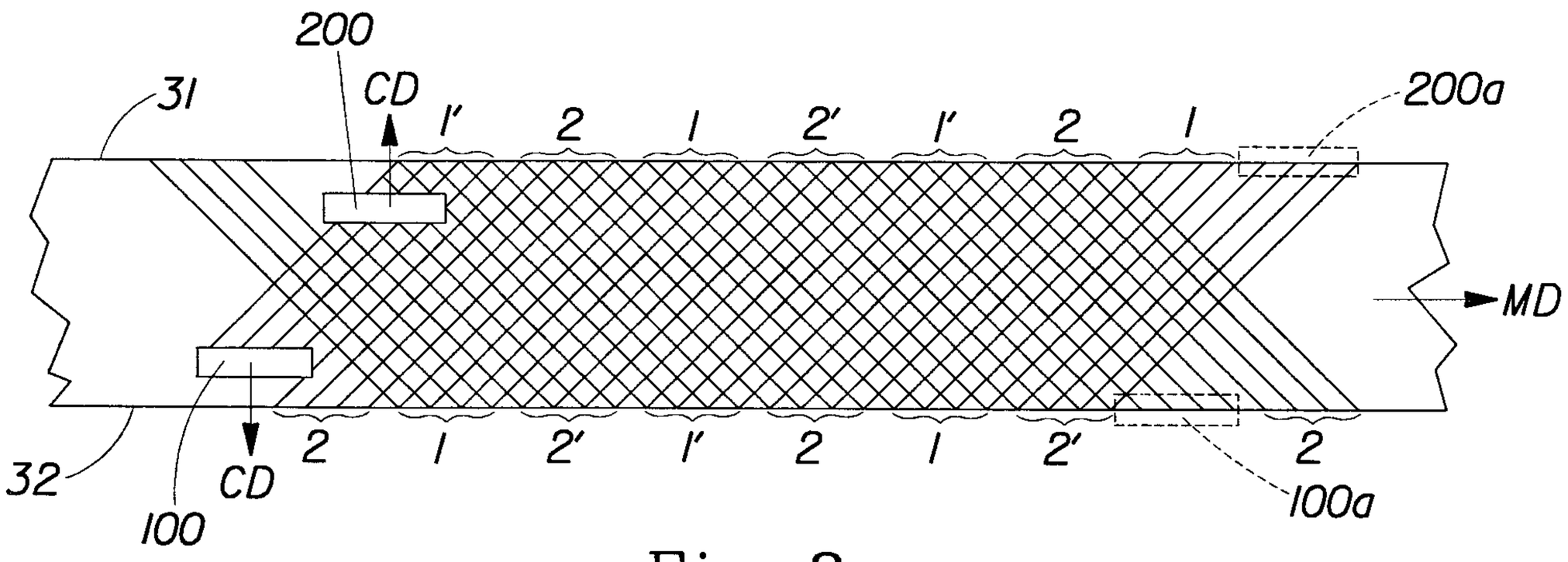


Fig. 8

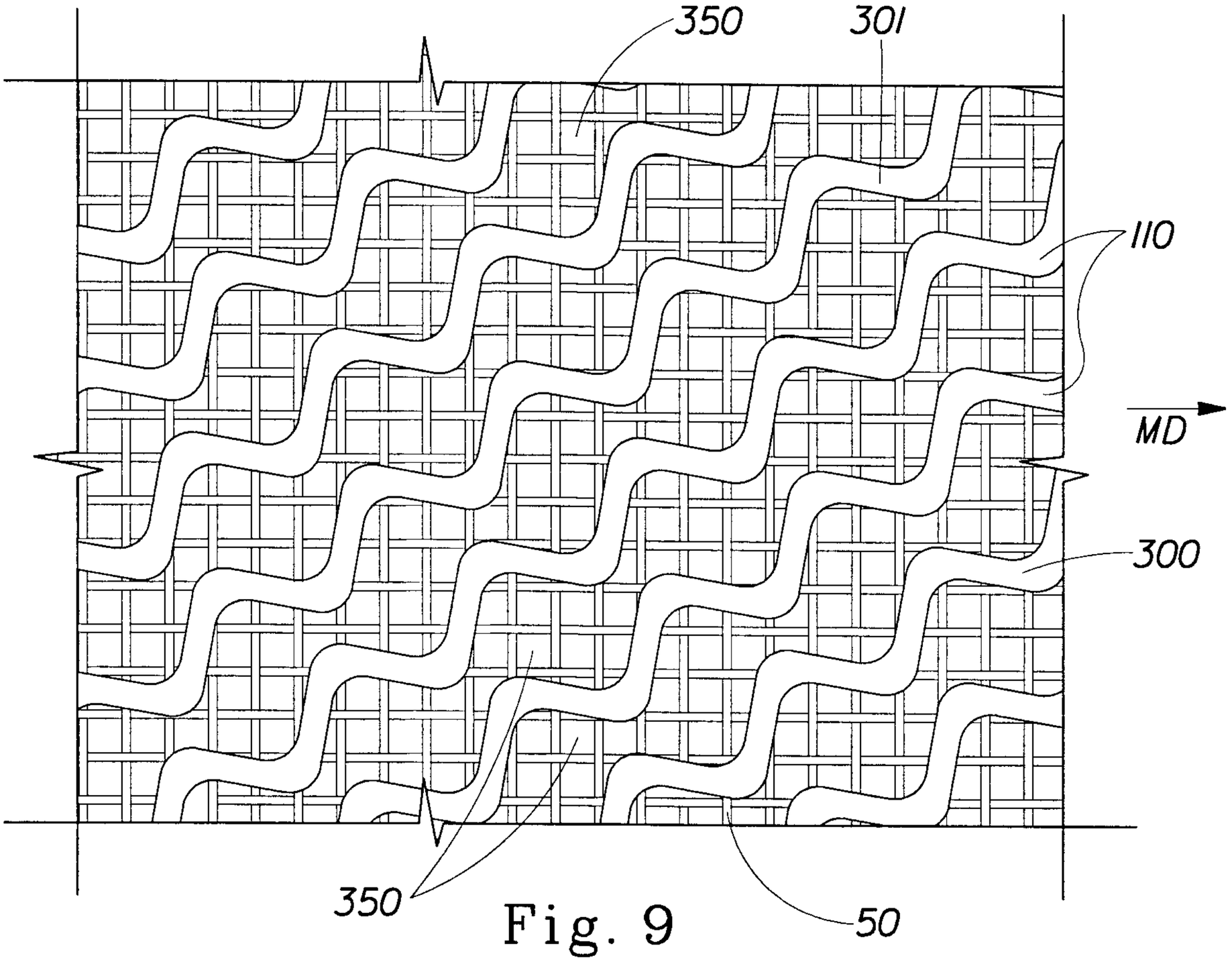


Fig. 9

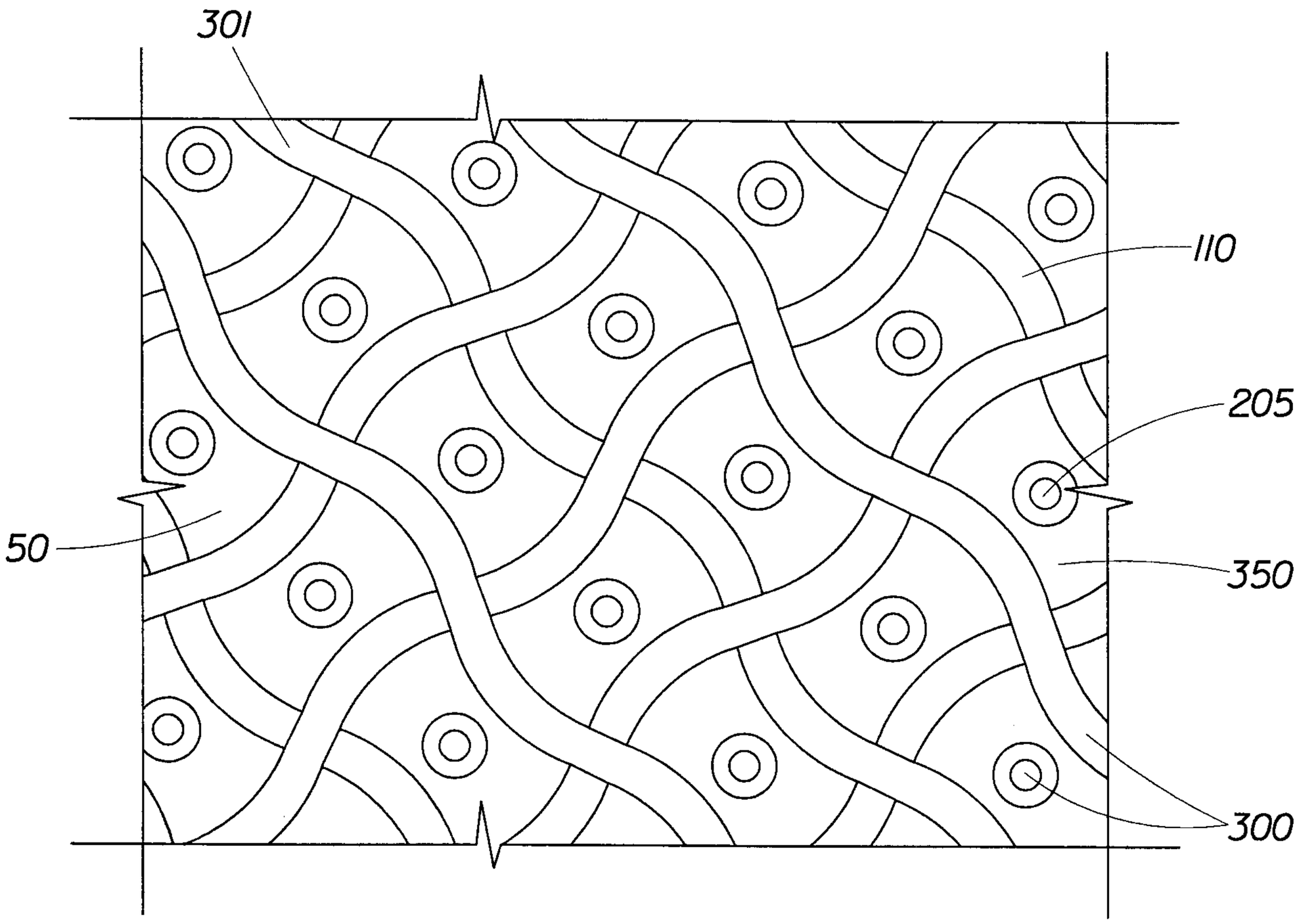


Fig. 10

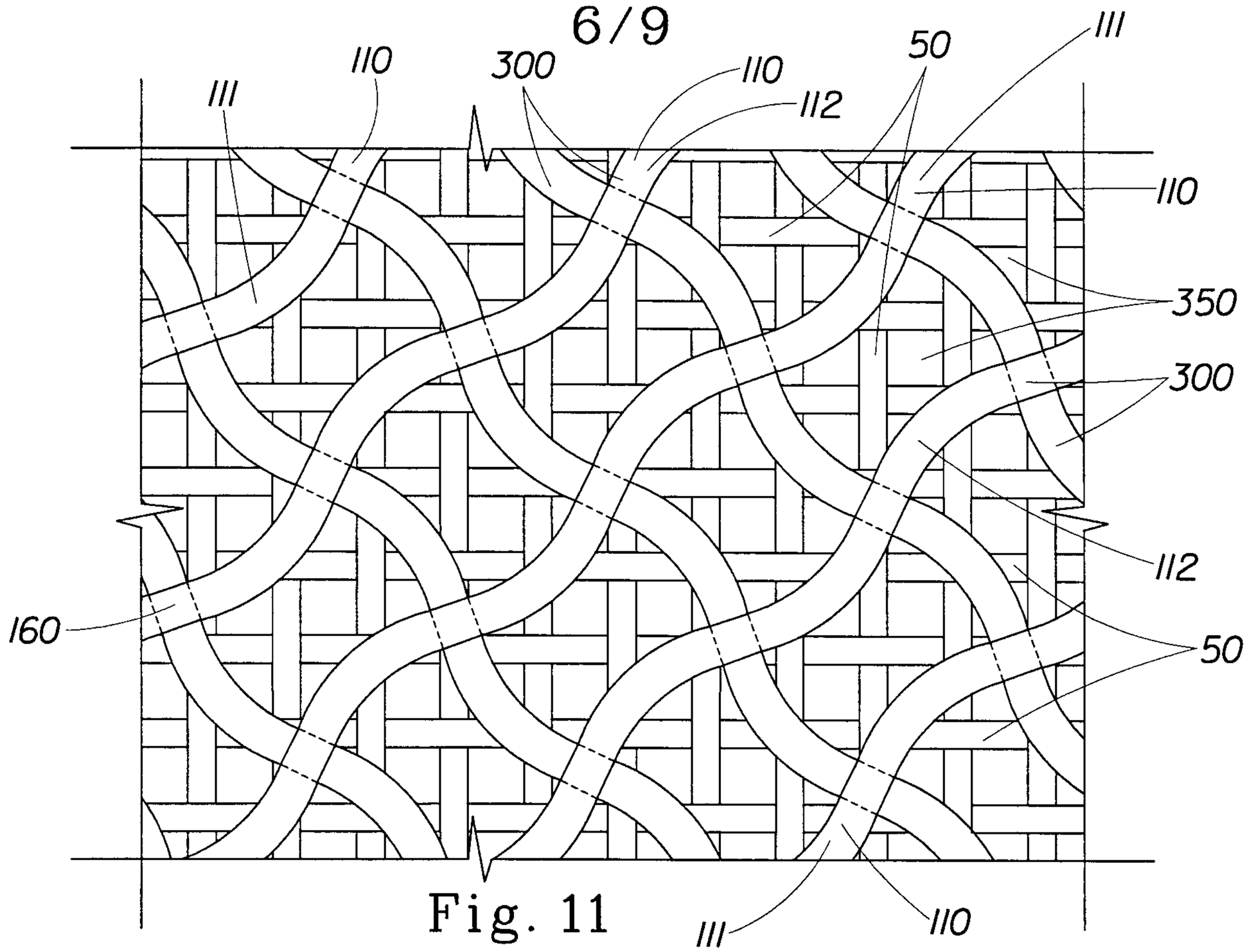

111
110
300
110
112
50
111
110
350
300
112
50
160
111
110

Fig. 11

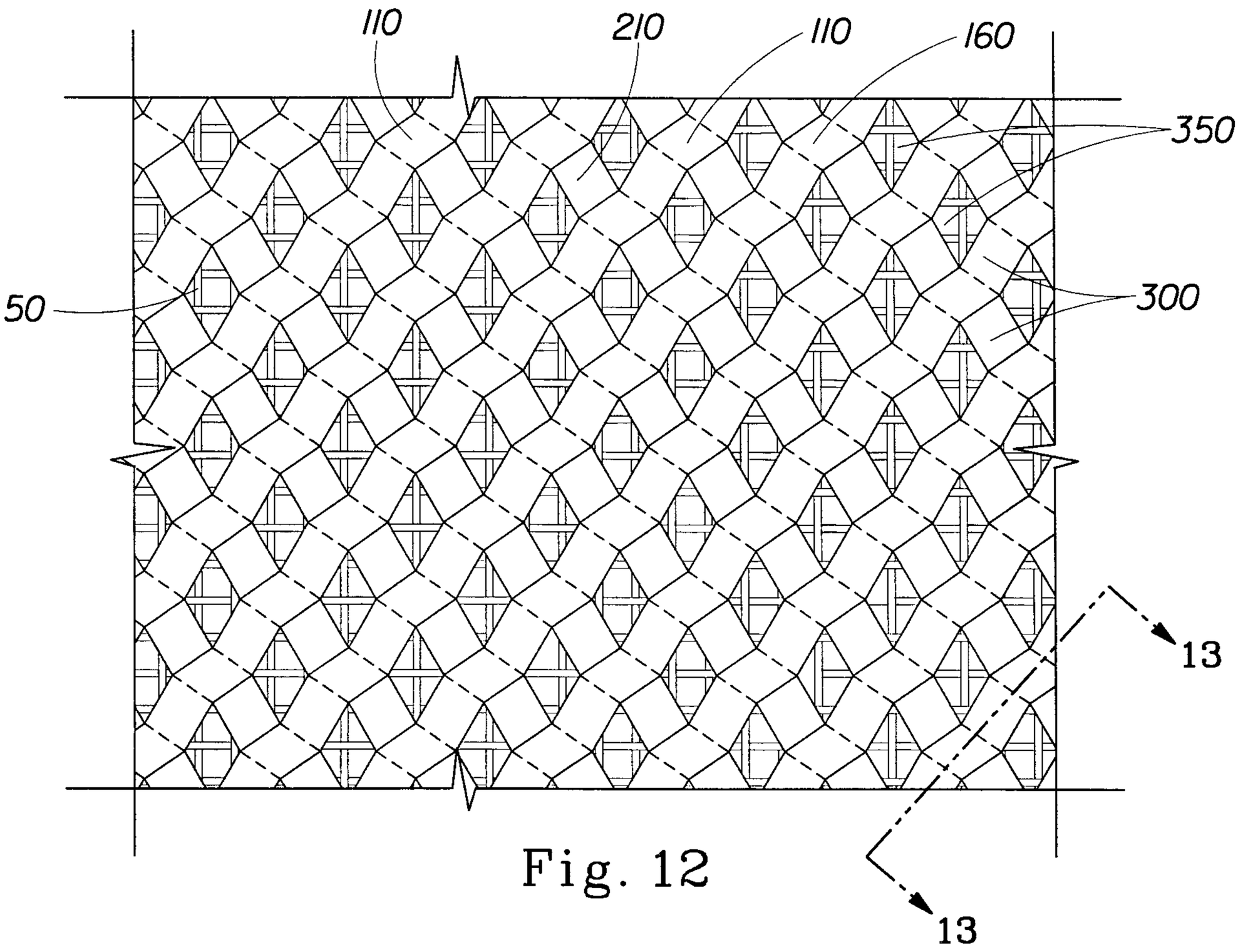

110
210
110
160
350
50
300
13
13

Fig. 12

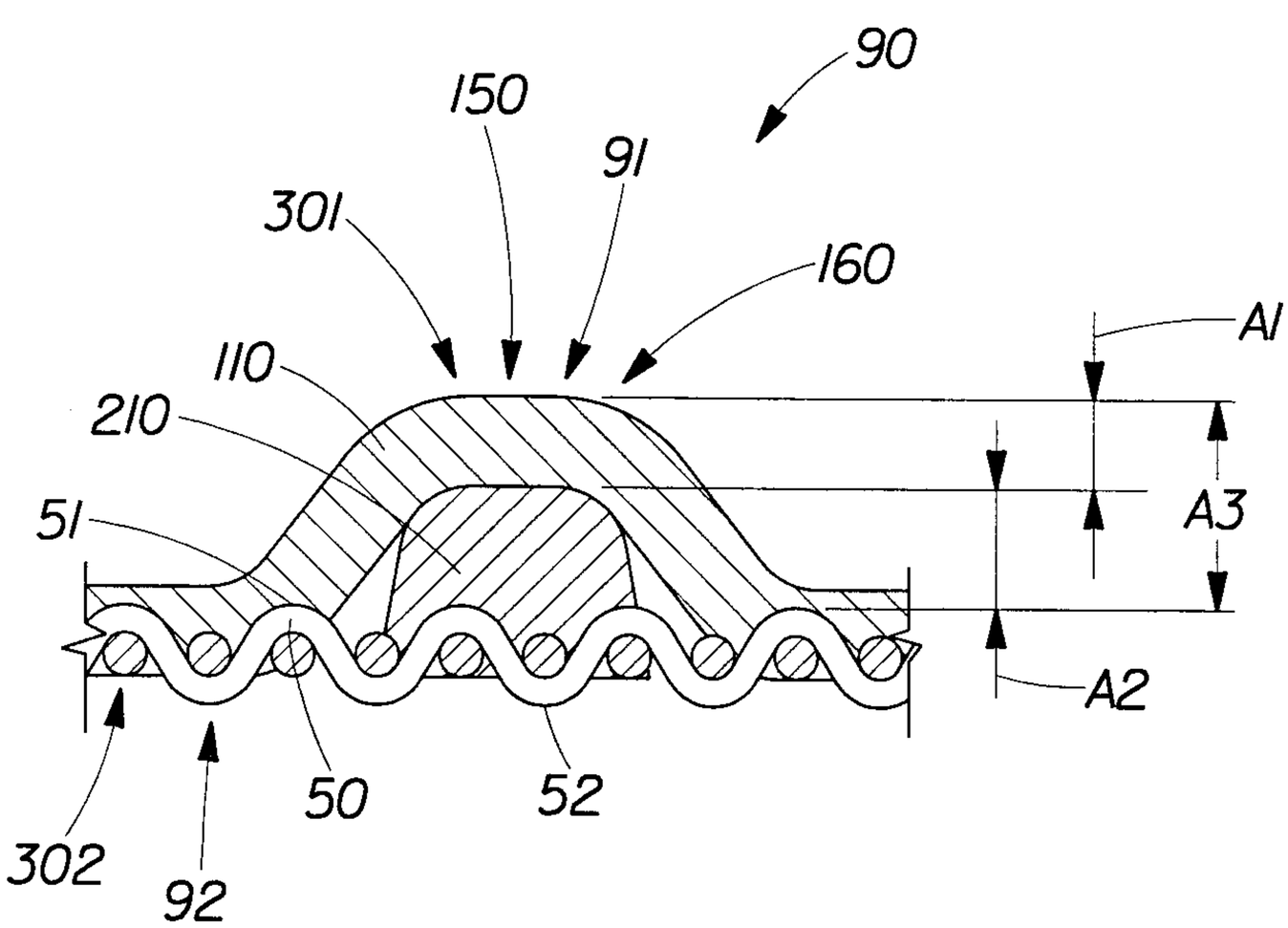


Fig. 13

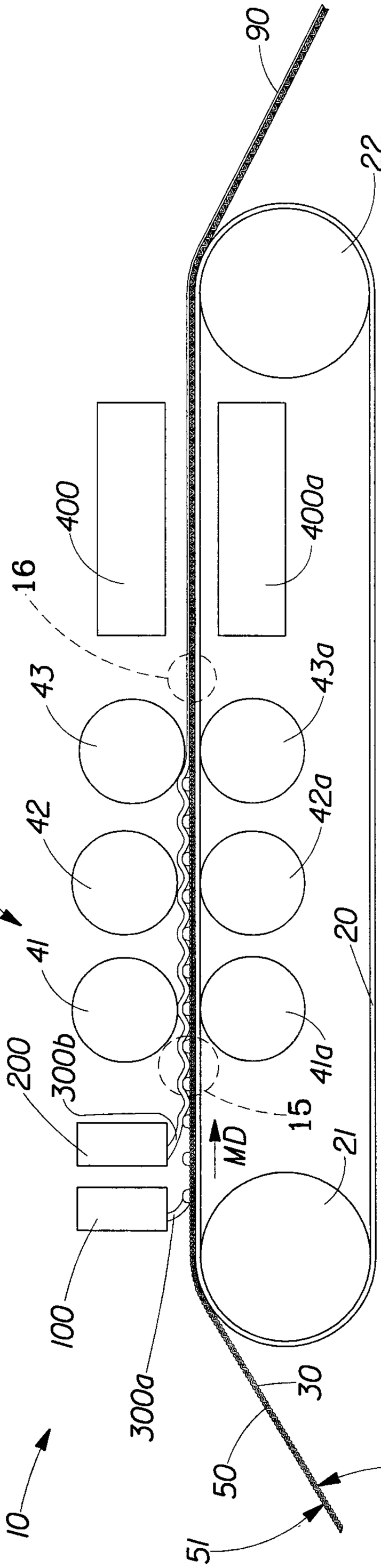


Fig. 14

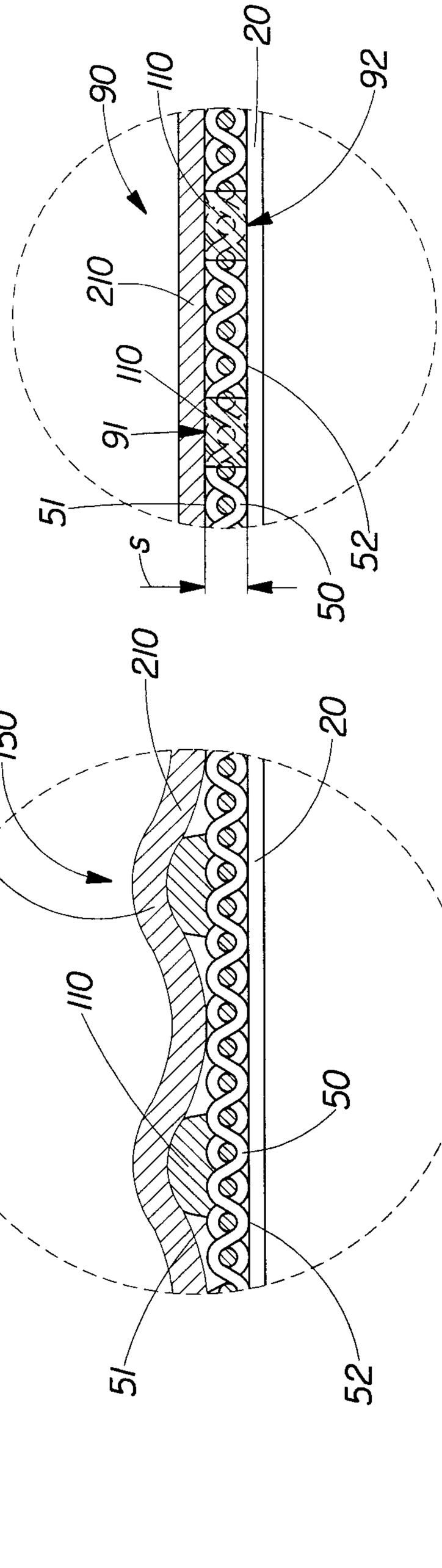


Fig. 16

Fig. 15

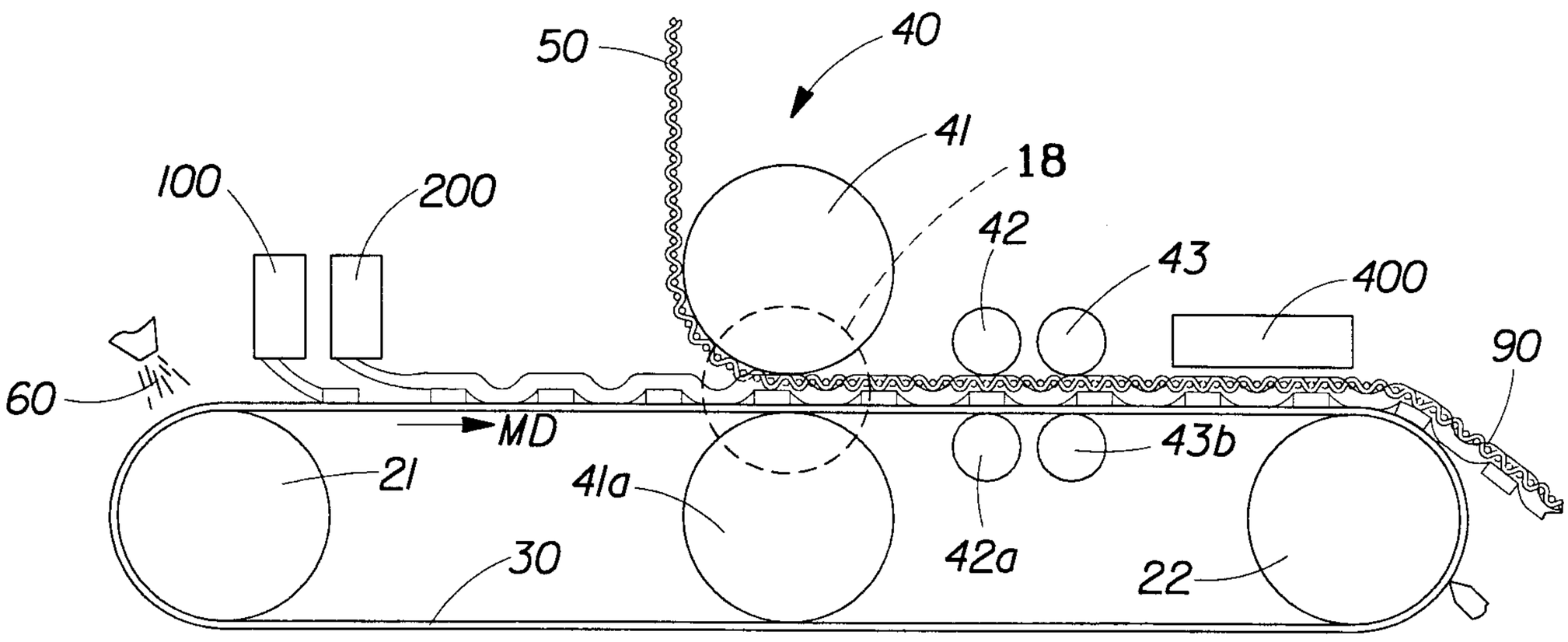

50
40
41
18
100
200
42
43
400
90
60
MD
43b
21
41a
42a
30
22

Fig. 17

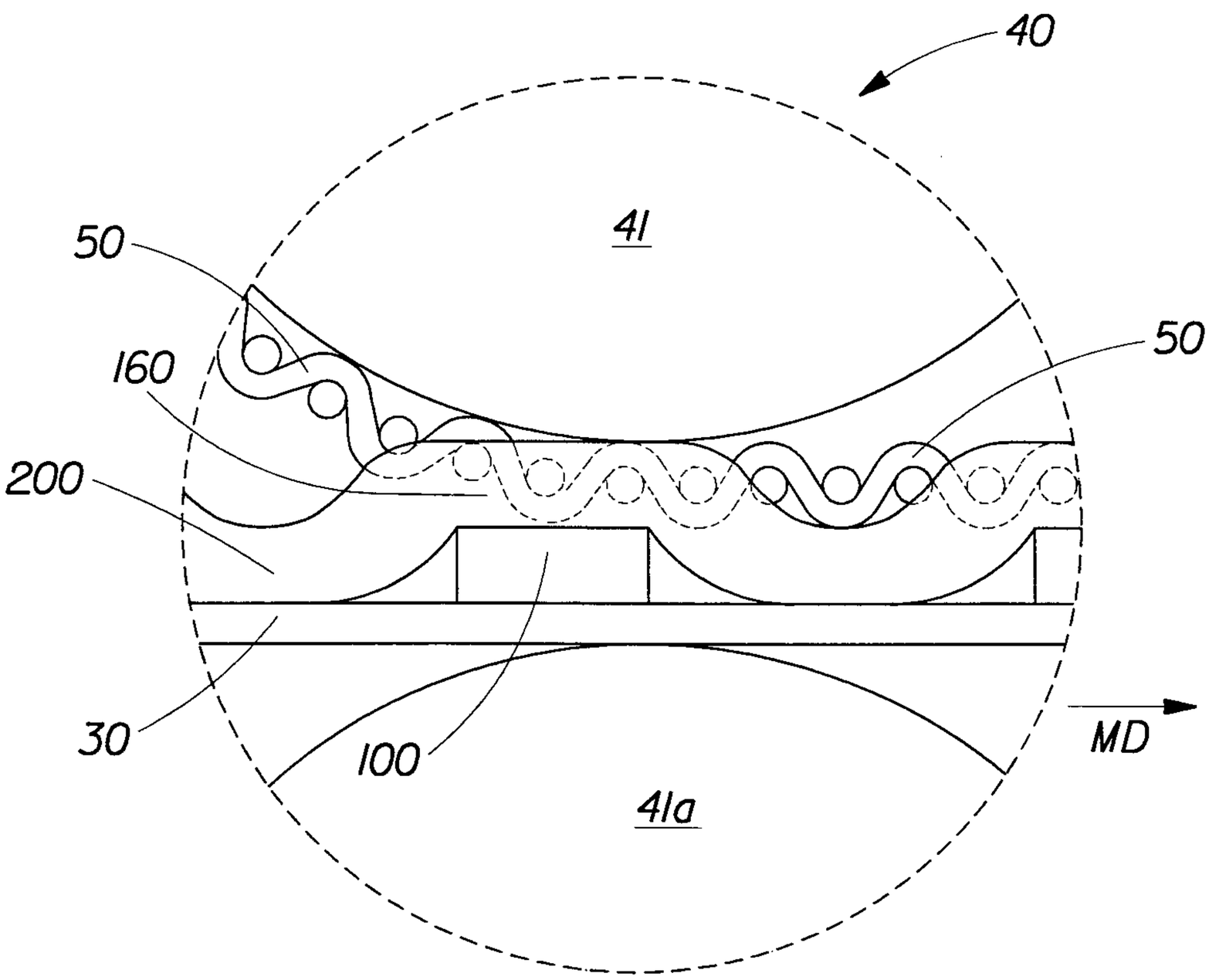
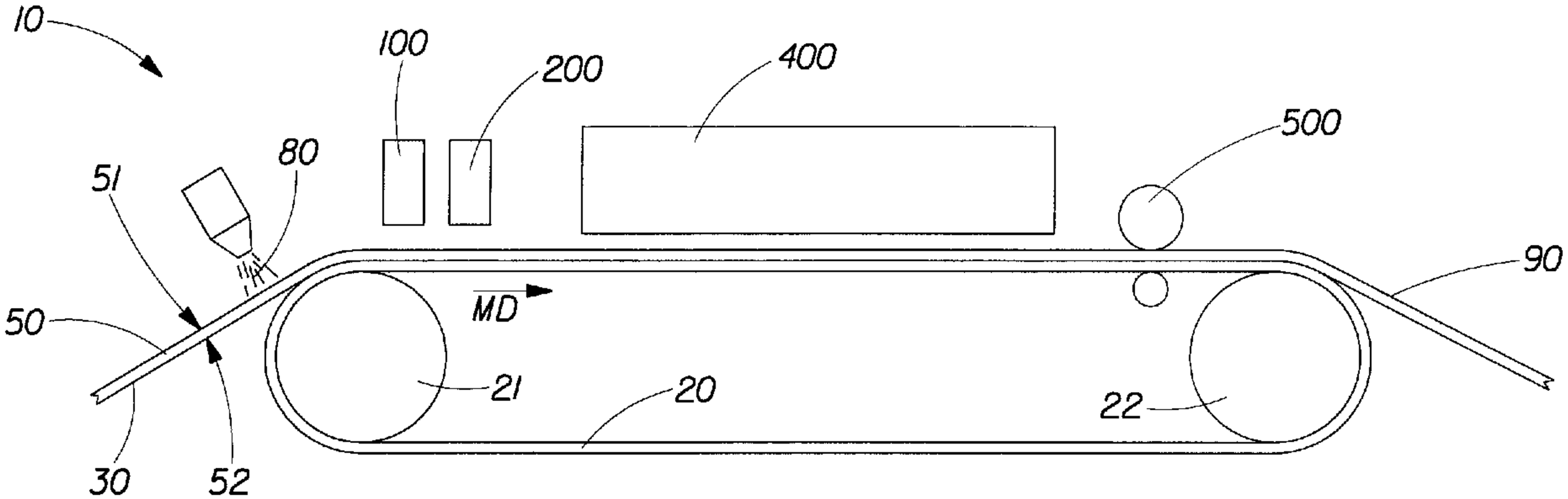

40
41
50
160
50
200
30
100
MD
41a

Fig. 18


10
100
200
400
500
80
51
50
MD
90
21
20
22
30
52