

SYSTEM AND METHOD FOR WINDING POLYMERIC FILMS, SUCH AS LOW MODULUS, POLYOLEFIN FILMS

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Background

The present invention relates to systems and methods for winding polymeric films in forming a wound roll. More particularly, it relates to systems and methods for
10 minimizing occurrences of winding-related defects when winding polymeric films, for example winding low modulus films such as optical grade, low modulus polypropylene film.

Polymeric films are conventionally manufactured in roll form. Regardless of exact composition of the film, large scale production generally entails forming a continuous
15 length or web of the film, and then winding the so-formed web about a rotating cylinder (or about a core mounted to the cylinder). For example, accepted polymeric film formation techniques include extruding a molten or melted resin (otherwise consisting of desired materials) to form a cast sheet or web. The cast web is stretched (e.g., uniaxially or biaxially stretched), for example using a length orienter and/or tenter, to impart desired
20 tensile properties to the film before being wound at a winding station. Wound film may be trimmed or slit into more than one width and wound into at least as many rolls. Optionally, wound film may be allowed to set or age, requiring the film to be unwound and then re-wound at optionally a second winding station. In those instances where the film is optionally aged, the initially formed film is wound into what is referred to as a mill
25 roll; subsequently, an optional second slitting operation is performed to slit or cut the mill roll into smaller width film lengths, which are in turn wound into stock or slit rolls at a separate winding station.

When provided as part of a continuous in-line manufacturing system, standard film winding devices are readily able to meet desired production speeds. That is to say, the
30 cylinder/core about which the film is wound can rotate at high speeds, resulting in a tightly wound roll for subsequent distribution and/or processing (e.g., slitting and rewinding of a

mill roll to form two or more stock rolls). Unfortunately, however, the high winding speeds, along with various film properties, can impart defects into the wound layers of film during winding. For example, non-uniform tensions and/or pressures are oftentimes imparted to the film during winding (e.g., at the outermost wound layer) due to various factors such as tolerance deviations in the winding device (e.g., tolerance run-outs in the winding cylinder), film stability at the winding device, caliper control of the film, etc. The resulting unevenness between the two wound layers (e.g., the outermost wound layer and an immediately underlying wound layer) can produce a wound-in defect(s) that later “grows” as multiple successive windings layers of the film are wound on top of the defect(s). These winding-induced defects can include tin can-type defects (e.g., the film roll exhibits a series of raised annular bands so as to resemble the side of a tin can), slip knots and gauge band types of defects. In this regard, while efforts are made to precisely design and build the mechanical components of the winding device, for large film width winding applications (e.g., on the order of 2 meters or greater), unavoidable precision runouts inherently produce non-uniform tension during winding; in instances where the affected film layer is unable to readily move (or relax) relative to the immediately underlying layer (e.g., due to friction), one or more of the winding-induced defects mentioned above can occur. Winding defects are typically more frequently observed when the film is thin.

A number of techniques have been used to aid winding. For example, it is known that the addition of slip particles or additives can reduce winding defects. However, films intended for optical applications can require minimal haze, and haze may be increased with the use of slip particles or additives. Also, winding defects in such optical grade films may manifest as changes in other intended optical properties. One example might be the formation of hard bands that locally stretch the film or alter its thickness. Additionally, if the desired optical properties of the film include optical phase retardation, as in the case of compensation films, hard bands and other winding defects may reduce the manufacturing yield for the manufacturer and/or quality of the product for the customer.

Beyond implementation of strict process control parameters, a long-practiced technique for minimizing winding-induced defects is to impart a knurl adjacent the opposing edges of the film (in the machine direction) prior to winding. The knurls are

physically created, and theoretically inhibit overt movement or “slipping” of wound layers relative to one another, as described, for example, in U.S. Patent Nos. 3,502,765 and 4,021,179. In addition and/or alternatively, various components can be added to the film composition to promote desired winding properties, such as a slip additive and/or silica or other “grippy” material.

While the above techniques have been found to greatly reduce occurrence of winding-induced defects for many types of films, they represent added manufacturing costs and, for other film constructions, either do not provide satisfactory results or are simply unavailable. For example, films exhibiting a relatively low tensile modulus, as well as relatively thin films, may not be amenable to the creation and maintenance of physically-imparted knurls. Thus, for example, physically knurling thin, low modulus polypropylene films has been found to not eliminate winding-induced defects. Further, regardless of the film construction, knurling devices can accumulate contaminants (e.g., dirt) over time, with these contaminants being undesirably transferred to subsequently-processed film. In addition, end use requirements may prohibit incorporating a slip agent, silica, or other material typically found to enhance winding properties. For example, optical grade films (e.g., birefringence optical films such as simultaneously biaxially oriented polyolefin films useful for enhancing viewing characteristics of a display, such as liquid crystal display) must satisfy stringent optical clarity requirements that are otherwise negatively impacted by the materials mentioned above.

While it may be possible to design and construct the winding device components to more exacting tolerances in an effort to hopefully reduce or eliminate winding-induced defects, the resulting device is likely to be cost prohibitive and thus not commercially viable, especially at the increasingly larger mill roll widths desired by film line manufacturers. In light of this constraint, a more desirable solution would entail modifying existing in-line film manufacturing/winding systems. Unfortunately, no such solutions are currently available.

Conventional film line manufacturing equipment is susceptible to winding-induced defects, and accepted solutions to this problem are expensive and may not be viable for

various film constructions. Therefore, needs exist for an improved film manufacturing and winding systems and methods.

Summary

The present application discloses, *inter alia*, a method of winding a polymeric film.

5 The method includes providing a length of polymeric film along with at least one small diameter strand apart from the polymeric film. The film and the strand are simultaneously wound about a cylinder to form a wound roll having successively wound layers of film. In this regard, relative to the wound roll, the strand is continuously interposed between successively wound layers of film, with the strand establishing a gap between an

10 outermost wound layer of film and an immediately underlying wound layer of film. With this methodology, the gap facilitates natural movement (e.g., relaxation) of the outermost wound layer relative to the immediately underlying wound layer, thereby compensating for any inherent unevenness of the cylinder and/or other components associated with the winding device. In some embodiments, the strand is laterally moved (e.g., oscillated)

15 relative to a width of the film with continuous winding, so as to minimize overt protrusions in the wound roll. In other embodiments, a plurality of small diameter strands are provided, with the strands being discretely spaced from one another relative to the film's width. In yet other embodiments, the film has a width of at least 4 meters, and a plurality of small diameter strands are provided, with the strands being discretely spaced

20 from one another relative to the film's width, the position of said strands outside of the region or regions where the film is expected to be used in one or more additional or downstream processes. Additional processes might include such operations as slitting or converting, surface treatment, coating, lamination or the like. In yet other embodiments, the polymeric film is a low modulus, optical grade film, such as a low modulus

25 polypropylene film adapted for use as a liquid crystal display compensator.

The present application also describes a system for manufacturing a wound roll of polymeric film. The system includes a polymeric film supply device, a winding device, and a film spacer. The polymeric film supply device provides a web of polymeric film from an exit thereof. The winding device includes a rotatable cylinder positioned to

30 receive the polymeric film web from the film supply device at a wind interface that is

otherwise defined relative to the cylinder. The film spacer is adapted to supply a continuous length of small diameter strand to the wind interface. With this in mind, the system is configured to simultaneously wind the polymeric film from the film supply device and the strand from the film spacer about the cylinder such that the strand is continuously interposed between successively wound layers of film. In some embodiments, the film spacer includes a source of the strand and an oscillation device for moving the strand laterally relative to the cylinder. In other embodiments, the polymeric film supply device includes an extruder for extruding a film from a melted resin. With this in mind, the extruder is in-line with the winding device, and the film spacer is positioned between the tenter and the winding device.

These and other aspects of the present application will be apparent from the detailed description below. In no event, however, should the above summaries be construed as limitations on the claimed subject matter which subject matter is defined solely by the attached claims, as may be amended during prosecution.

Brief Description of the Drawings

The accompanying drawings are included to help describe the present invention. The elements of the drawings are not necessarily to scale relative to each other. Like reference numerals designate like parts.

FIG. 1 is a block diagram of a system for winding a polymeric film provided as part of a polymeric film production line;

FIG. 2A is a block diagram of a film spacer useful with the winding system of FIG. 1;

FIG. 2B is a schematic illustration of the film spacer of FIG. 2A;

FIG. 3A is a schematic side view of portions of the winding system of FIGS. 1 and 2A in connection with a web of polymeric film;

FIG. 3B is a schematic top view of the arrangement of FIG. 3A;

FIG. 3C is a schematic top view of another winding system arrangement in connection with a polymeric film web;

FIGS. 4A-4C schematically illustrate simultaneous winding of a polymeric film and a strand;

5 FIG. 5 is a simplified, cross-sectional view of the polymeric film and strands during a winding operation;

FIG. 6A is a schematic top view of a polymeric film and strands during winding;

FIG. 6B schematically illustrates the film and strands of FIG. 6A in an unwound state; and

10 FIG. 7 is a side view of a wound roll following processing by the system of FIG. 1.

Detailed Description

A winding system 20 for winding a polymeric film is shown as part of a polymeric film manufacturing line 22 in FIG. 1. As described in greater detail below, the winding system 20 is adapted to wind polymeric film into roll form, with the polymeric film initially being provided or generated by a polymeric film supply device 24. In this regard, the film supply device 24 can assume a wide variety of forms, and generates or provides a web (e.g., a continuous web) of polymeric film 26 (illustrated generally in FIG. 1) to the winding system 20. The winding system 20 generally includes a winding device 28 and a film spacer 30. The winding device 28 is generally sized and adapted to effectuate winding of the film web 26 as a wound roll, with the film spacer 30 creating a slight gap between at least an outermost wound layer and an immediately underlying wound layer of film during winding, with this gap(s) facilitating movement (e.g., relaxation) of the outermost wound layer relative to the immediately underlying wound layer in a manner that reduces occurrences of winding-induced defects in the wound roll.

25 As indicated above, the manufacturing line 22, and in particular the polymeric film supply device 24, can be akin to conventional film line manufacturing devices typically used to manufacture polymeric film. For example, the polymeric film supply device 24

can include a resin handling/storage station 40, an extruder 42, a die/casting station 44, and a tenter 46. In general terms, desired resin constituents are maintained and/or combined within the resin handling station 40 and then supplied to the extruder 42. The extruder 42 melts the resin, and then extrudes the molten resin to the die/casting station 44.

5 The die/casting station 44 effectuates desired hardening of the extruded cast melt to produce a cast sheet. The cast sheet is then stretched (e.g., biaxially stretched in the longitudinal and transverse directions) to form the polymeric film web 26. The stretched film web 26 can then be subjected to various other processes to effectuate desired film characteristics. Alternatively, the film web 26 can be produced by a cast film process

10 followed by no stretching, sequential stretching, or either sequential or simultaneous biaxial stretching. Other film forming techniques can also be employed, such as, for example, a blown film process. Regardless, the resultant film web 26 is produced and supplied to the winding system 20 from an exit 48 (referenced generally) thereof. It will be understood, however, that this is but one acceptable system or technique for supplying

15 the film web 26 to the winding system 20. In other embodiments, for example, the film web 26 can be created off-line relative to the winding system 20 (e.g., the film web 26 can be subjected to other processing following initial manufacture and then provided to the winding system 20).

As a point of reference, the winding system 20 described herein is useful with a

20 wide variety of different polymeric film constructions. Thus, the winding system 20 can be employed to form wound rolls of film having different material constructions, thicknesses, physical properties (e.g., tensile modulus), optical properties, etc. In some embodiments, however, the winding system 20 is highly appropriate for winding or processing polymeric films that are otherwise likely to experience winding-induced

25 defects using conventional winding devices (such as the winding device 28) and/or that are otherwise not amenable to the use of resin additives that have otherwise been found to improve winding properties. For example, the winding system 20 is highly useful with thin films (films having a thickness of less than about 50 microns, and including very thin films having a thickness of less than about 25 microns). Similarly, the winding system 20

30 is highly useful in winding films having a low tensile modulus (e.g., a modulus of less than about 2.0 – 2.75 GPa, such as polyolefin films including polypropylene). As previously described, films exhibiting one or both of these properties cannot be adequately

knurled and/or continue to experience winding-induced defects following knurling. Similarly, films formulated for optical applications, such as optical displays or optical compensators for displays (e.g., liquid crystal displays) cannot include conventional modifiers such as slip agents or silica, normally understood to improve winding properties.

5 The winding system 20 is highly appropriate for winding these optical grade films, where the phrase “optical grade film” is defined as a film that is free of surface defects and/or undesired optical artifacts that can cause a localized change in, for example, the birefringence, transparency or haze of the film. As a point of reference, acceptable polymeric optical grade films with which the winding system 20 is useful are described, 10 for example, in U.S. Patent No. 6,965,474 and U.S. Publication No. 2004/0156000, the teachings of which are incorporated herein by reference and that otherwise describe simultaneously biaxially stretched optical grade polymeric films. Thus, for example, in some embodiments, the winding system 20 along with the corresponding winding method described herein is used in connection with a highly thin (e.g., on the order of 15-20 15 microns), low modulus optical grade polypropylene film.

With the above background in mind, the film spacer 30 in accordance with some aspects of the present application is shown schematically in FIG. 2A in conjunction with the winding device 28 otherwise illustrated in block form. As a point of reference, the winding device 28 can be akin to a conventional film winder (e.g., film winders available 20 from Bruckner, Inc., of Greenville, SC), and generally includes a cylinder 50 about which the film web 26 (FIG. 1) is wound. The cylinder 50 is driven to effectuate winding of the film 26, and thus has a longitudinal length corresponding with (i.e., slightly larger than) a cross-web width of the film 26. In some embodiments, for example, the film 26 can have a width of at least 4 meters, and in some embodiments a width greater than 6 meters, and 25 yet other embodiments, a width that is greater than 10 meters; the cylinder 50 thus has a corresponding longitudinal length. In addition, the winding device 28 can include additional components (not shown) and can be configured such that a core (not shown) is assembled over the cylinder 50 and about which the film 26 is wound.

Regardless of an exact construction of the winding device 28, the film spacer 30 of 30 FIG. 2A includes a strand 60 supplied by a strand source 62. The strand 60 extends from the strand source 62, and is acted upon by a tension device 64 and a guide device 66 as

described below. The tension device 64 and the guide device 66 effectuate a desired tension and position of the strand 60 as it is fed to the winding device 28, and in particular the cylinder 50. In general terms, the strand 60 is simultaneously wound with the film 26 (FIG. 1) about the cylinder 50, and serves to minimize occurrences of random, winding-induced defects in the resultant wound roll (not shown).

The strand 60 can assume a variety of forms, and is provided apart from the film 26 (FIG. 1). The strand 60 can be a monofilament or multifilament material (e.g., a multifilament yarn such as a multifilament texturized nylon yarn available from Texfi Industries of Raleigh, NC under the trade designation 1:20:7:S Twist:Nylon 6 to identify but one acceptable material). The strand 60 is selected to be compatible with the film 26 (e.g., will not deteriorate a quality of the film 26 when placed in intimate contact therewith), and has a relatively small diameter or major dimension as compared to a thickness of the film 26. For example, a diameter or major dimension of the strand 60 is less than the thickness of the film 26; preferably less than 50% of the thickness of the film; and more preferably less than 10% of the thickness of the film. In other embodiments, the relative small diameter or major dimension of the strand 60 is characterized as being not more than 50 Denier; in other embodiments not more than 25 Denier; and in yet other embodiments not more than 5 Denier. With this construction, then, the strand 60 will directly impinge upon only a very small lateral segment of the wound film, yet effectuates desired spacing between wound layers as described below.

The tension device 64 is optionally provided as part of the spacer assembly 30, and is adapted to create a level of tension in the strand 60 with extension of the strand 60 from the source 62 to guide device 66. More particularly, as the strand 60 is continuously pulled from the guide device 66 (e.g., with continuous winding of the strand 60 about the cylinder 50), the tension device 64 maintains a small amount of tension in the strand 60 between the guide device 66 and the source 62 to prevent formation of slack in the strand 60. Thus, the tension device 64 can assume a wide variety of forms appropriate for use with the particular construction of the strand 60. For example, the tension device 64 can include or entail a body applying a small weight or mass onto the strand 60 as the strand 60 is continuously pulled (via the winding device 28) from the guide device 66, and thus from the source 62. As a point of reference, tension created or applied by the tension

device 64 need only be enough to avoid formation of slack in the strand 60, and should not exceed a tensile strength of the strand 60 in a manner that might otherwise cause the strand 60 to break or fray. In yet other embodiments, the tensioning device 64 can be eliminated.

The guide or guide device 66 can also assume a wide variety of forms, and is generally constructed to position the strand 60 at a desired lateral location relative to the cylinder 50 for subsequent winding with the film 26 (FIG. 1). For example, and with additional reference to FIG. 2B, the guide device 66 can include an arm 68 terminating at an eyelet or other opening 70 through which the strand 60 is threaded and extends. In other embodiments, the guide device 66 is further configured to effectuate lateral or side-to-side movement of the strand 60 in a desired fashion relative to the cylinder 50 (and thus relative to the film 26 as the film 26/strand 60 are simultaneously wound). For example, a base 72 of the arm 68 is slidably assembled within a slot 74 of a frame 76, and is further driven or moved within the slot 74 via a motorized connection 78 (referenced generally). With this configuration, the motorized connection 78 can operate to articulate the arm 68, and thus the strand 60 extending therefrom, in a transverse or lateral fashion relative to the cylinder 50. Alternatively, a wide variety of other configurations capable of effectuating lateral movement of the strand 60 are also acceptable, including rocking, oscillating or otherwise changing the lateral position of the strand. As described below, the guide device 66 can operate in an oscillating fashion, laterally moving or changing a position of the strand 60 over a small distance (e.g., not more than 4 inches; alternatively not more than 3 inches; alternatively not more than 2 inches) at a relatively slow oscillation rate (e.g., on the order of 0.5 – 2.0 cycles per minute).

Arrangement of the winding device 28 and the film spacer 30 can be described with reference to FIGS. 3A and 3B. In particular, FIGS. 3A and 3B schematically illustrate the cylinder 50 otherwise provided as part of the winding device 28 (FIG. 1), along with the film spacer 30 (referenced generally) including the strand 60 extending therefrom. Further, the film web 26 is also shown in a state prior to winding about the cylinder 50 (for ease of illustration, a thickness of the film 26 is exaggerated in the view of FIG. 3A, whereas a diameter of the cylinder 50 is reduced). With these conventions in mind, the film spacer 30 is generally spatially aligned with the cylinder 50 (and thus the film 26) such that as the film 26 and the strand 60 approach the cylinder 50 (for example

at a wind interface I otherwise established relative to the cylinder 50), the strand 60 will contact a major surface 90 of the film 26. While the arrangement of FIG. 3A reflects the strand 60 interfacing with a “lower” surface 90 of the film, the film spacer 30/strand 60 can alternatively be positioned to interface with an opposing “upper” surface 92 of the film 26.

As shown in FIG. 3B, the strand 60 is directed to a location laterally or transversely between opposed edges 94, 96 of the film 26 (it being understood that in the top view of FIG. 3B, the strand 60 is “behind” or below the film 26 such that FIG. 3B more generally reflects or denotes a point at which the strand 60 will initially contact the film 26). With this orientation, then, as the film 26 and the strand 60 are simultaneously pulled or directed to the cylinder 50 for subsequent winding, contact between the strand 60 at a point along a width W of the film 26 is ensured. With the configuration of FIG. 3B, the single strand 60 is illustrated as being approximately centered relative to the transverse width W of the film 26 (i.e., cross-web width of the film 26). Alternatively, however, the strand 60 can be positioned to contact the film 26 at any lateral position relative to the width W thereof. For example, the strand 60 can be located to interface with the film 26 at or adjacent one of the opposed edges 94 or 96. In yet other embodiments, the film spacer 30 (FIG. 1) can include a plurality of discretely positioned strands 60. One such arrangement is schematically illustrated in FIG. 3C as including the strands 60a-60d. The first strand 60a is located to contact the film 26 at or adjacent the first edge 94 upon simultaneous winding about the cylinder 50, whereas the second strand 60b is located to contact the film 26 at or adjacent the second edge 96. For applications in which the film 26 has a relatively large cross-web width W (e.g., greater than 4 meters), one or more additional strand(s) can be provided, such as the strands 60c and 60d as shown. In general terms, the strands 60a-60d are discretely spaced from one another, with the third and fourth strands 60c, 60d being transversely positioned more closely to a longitudinal centerline of the film 26. In other embodiments, five or more of the strands 60 can be provided, each of which are again discretely spaced from one another relative to the width W of the film 26. Regardless of an exact number, the apparatus employed to direct or locate the corresponding strand 60 relative to the cylinder 50 is, in some embodiments, adapted to effectuate some local lateral movement of the strand(s) 60 relative to the web

26 (e.g., each of the strands 60a-60d of FIG. 3C extends through a laterally articulable guide device, such as the guide device 66 of FIG. 2B).

Simultaneous winding of the strand 60 and the film 26 about the cylinder 50 can be described with reference to FIGS. 4A-4C. For purposes of clarity, a thickness of the film 26 is exaggerated in the views, whereas a diameter of the cylinder 50 is reduced. With this in mind, simultaneous winding of the film 26 and the strand 60 begins at FIG. 4A (it being noted that while only one strand 60 is illustrated, two or more discretely positioned strands 60 can alternatively be employed as previously described). In particular, a leading end 98 of the film 26 is brought toward the cylinder 50, along with a leading end 100 of the strand 60. In this regard, one or both of the film 26 and/or strand 60 can be manually directed toward the cylinder 50, or mechanical devices (not shown) can be employed, etc. Regardless, the strand 60, that is otherwise initially provided apart from the film 26, is secured to the surface 90 of the film 26 such that the leading end 100 of the strand 60 is adjacent the leading end 98 of the film 26. For example, tape (e.g., a pressure sensitive adhesive tape strip), adhesive, etc., can be used to couple the strand 60 at leading end 100 to the leading end 98 of the film 26. Another example of initially adhering the strand 60 to the film 26 takes advantage of a natural attraction (such as tack or static forces) of the strand 60 and the film 26, the natural attraction depending at least in part upon the choice of materials and manufacturing processes of the strand and film. Alternatively, the leading end 100 of the strand 60 can be spaced from the leading end 98 of the film 26 (relative to a longitudinal length of the film 26), for example by first initiating winding of the film 26 about the cylinder 50 and then coupling the strand 60 to the surface 90 as shown. In either case, the film 26/strand 60 is directed toward the cylinder 50 and simultaneous winding of the film 26/strand 60 is initiated.

The film 26/strand 60 are partially wound about the cylinder 50 in the view of FIG. 4B. As a point of reference, while the figures reflect the film 26/strand 60 being placed in direct contact with a surface of the cylinder 50, in other embodiments, a tubular core is placed over the cylinder 50, with the film 26/strand 60 placed in contact with, and thus, wound about, the core. Regardless, FIG. 4B illustrates the wind interface I theoretically defined by the cylinder 50 relative to the film 26/strand 60. As used throughout the specification, the wind interface I is defined as the point at which winding of the film 26

about the cylinder 50 initiates, and thus can also be viewed as an “entrance” of the cylinder 50. With these conventions in mind, then, FIG. 4B reflects that relative to the wind interface I, the film 26 is defined by a wound segment 110 downstream of the wind interface I, and an unwound segment 112 upstream of the wind interface I. With continued rotation of the cylinder 50 (e.g., clockwise relative to the views of FIGS. 4A-4C), the film 26 and the strand 60 are continuously and simultaneously wound about the cylinder 50, with the wound segment 110 of the film 26 continuously increasing in longitudinal length.

As shown in FIG. 4C, the film 26/strand 60 is continuously wound about the cylinder 50 to define a wound roll 114. In this regard, the film 26 continues to define the wound and unwound segments 110, 112, with the wound segment 110 of the film 26 having multiple wound layers or wraps 116 (referenced generally). For purposes of clarity, the film 26 is shown with cross-hatching in FIG. 4C to better distinguish each of the wound layers 116, it being understood that the wound layers 116 are part of a singular extension of the film 26. In particular, as part of the wound roll 114 forms, the film 26 includes an outermost wound layer 116a, an immediately underlying wound layer 116b, and additional, sequentially interior wound layers 116c, 116d. In this regard, the unwound segment 112 transitions to the outermost wound layer 116a at the wind interface I, and the immediately underlying wound layer 116b is defined as the next, successive winding from the outermost wound layer 116a. Additional wound layers 116 (such as the wound layers 116c, 116d) are thus defined as successive revolutions of the film 26 from the immediately underlying wound layer 116b. FIG. 4C further illustrates that with simultaneous winding of the film 26/strand 60, the strand 60 is continuously interposed between adjacent ones of the wound layers 116 of the film 26. Thus, for example, the strand 60 continuously extends between the outermost and immediately underlying wound layers of film 116a, 116b. As a point of reference, the strand 60 is illustrated in FIG. 4C as not being in contact with, or otherwise free of, the film 26 upstream of the wind interface I. This is indicative of one technique in which the strand 60 need only be physically attached to the film 26 prior to initiation of the winding operation (i.e., as described above with respect to FIG. 4A). As the film 26/strand 60 are simultaneously wrapped about the cylinder 50, a radial compressive force established by the wound film 26 prevents the strand 60 from laterally moving (i.e., into or out of the plane of FIG. 4C). Upstream of the wind interface

I, however, the strand 60 can be laterally manipulated relative to the film 26 (and thus relative to the cylinder 50) as described below.

With continuous winding of the film 26/strand 60, the strand 60 establishes a slight gap between at least the outermost and immediately underlying wound layers of film 116a, 116b. This relationship is further illustrated in FIG. 5 whereby first and second strands 60a, 60b are discretely positioned and continuously extend between adjacent ones of the wound layers of film 116 (referenced generally). Relative to the outermost and immediately underlying wound layers of film 116a, 116b, the strands 60a, 60b individually or collectively define one or more gaps 120 (referenced generally), with the gap(s) 120 being most prevalent at the wind interface I (best shown in FIG. 4C). In particular, as the film 26 is continually wound about the cylinder 50, inherent tension in the outermost wound layer 116a compresses the outermost wound layer 116a against the immediately underlying wound layer 116b. At least at the wind interface I, however, the strands 60a, 60b effectively space the outermost and immediately underlying wound layers 116a, 116b (via the gap(s) 120). This, in turn, affords the outermost wound layer 116a a degree of freedom relative to the immediately underlying wound layer 116b such that the outermost wound layer 116a can relax (or otherwise move) relative to the immediately underlying wound layer 116b, thus releasing or overcoming any naturally induced stresses that might otherwise result from tolerance deviations inherent to the cylinder 50 (or other components of the winding device 28 (FIG. 1)). As a result, occurrences of winding-induced defects are greatly reduced and even eliminated. As shown in FIG. 5, the gap(s) 120 between adjacent wound layers of film 116 is reduced and eventually eliminated with multiple windings of the film 26 (e.g., relative to the wound layers of film 116c, 116d, the gap(s) 120 no longer exists due to radially compressive forces inherent to the wound roll 114).

FIG. 5 further reflects that in some embodiments, a lateral position of the strands 60a, 60b (i.e., relative to the edges 94, 96 of the film 26 and thus relative to the cylinder 50) as slightly changed with each successive winding. In this regard, and as previously described, in some embodiments, the film spacer 30 (FIG. 2A and 2B) is configured to impart a lateral movement onto the corresponding strands 60a, 60b at a point prior to winding about the cylinder 50. For example, and with reference to FIG. 6A, the strands

60a, 60b are shown relative to the film 26, and in particular the unwound segment 112 and outermost wound layer 116a thereof. At a point P upstream of the wind interface I (referenced generally), the strands 60a, 60b are freely movable laterally relative to the corresponding edge 94, 96 of the film 26. Once wrapping of the film 26/strands 60a, 60b about the cylinder 50 is initiated (i.e., at the wind interface I), a lateral position of the strand 60a, 60b relative to the wound film segment 110 is essentially fixed.

In some embodiments, to avoid formation of an overt protrusion in the wound roll 114 (FIG. 4C) that might otherwise result were the strands 60a, 60b to be continuously aligned with successive windings, the strands 60a, 60b are moved in a lateral direction (represented by arrows in FIG. 6A) at the point P upstream of the wind interface I. Once again, this lateral movement is defined relative to the width W or transverse direction of the film 26. With embodiments in which the strands 60a, 60b are of a small diameter, a distance or period of travel D associated with the strands 60a, 60b can be relatively small, not more than 6 inches; alternatively not more than 4 inches, alternatively in the range of 1 – 3 inches; alternatively in the range of 1.5 – 2.0 inches. Relative to the cross-web width W of the film 26, the lateral distance of travel D can also be described as not being more than 10 percent of the cross-web width; alternatively not more than 5 percent; alternatively not more than 3 percent. In some embodiments, lateral movement of the strands 60a, 60b is performed on an oscillating basis, with the frequency of oscillation being not more than 5 cycles per minute; alternatively not more than 3 cycles per minute; alternatively in the range of 0.5 – 2 cycles/minute. Other oscillation periods and/or frequencies are also acceptable, and the strand(s) 60a, and/or 60b can be laterally moved in a non-oscillatory (e.g., non-uniform) manner. As shown by dashed lines in FIG. 6A, then, a path of the strands 60a, 60b relative to the corresponding edge 94, 96 of the film 26 is characterized by a changing lateral component. FIG. 6B further illustrates this relationship, whereby the film 26 is shown as being unwound from the cylinder 50 and the strands 60a, 60b have a laterally changing path along a longitudinal length of the film 26.

As a point of reference, it has been found that the effective space or gap between consecutive layers of film (due to the presence of the strand(s) 60) can be controlled during winding by controlling the distance or width the strand(s) 60 are oscillated (e.g., the distance of travel D) during winding. In this regard, the distance or width of oscillation

can be controlled in at least one of two manners. First, the actual distance of travel the mechanical oscillation device moves can be controlled. Alternatively, the speed of oscillation can be controlled. To this end, it has been found that distance or width of strand placement (relative to the film 26) can be narrowed by increasing the speed of oscillation, and can be widened by decreasing the speed of oscillation.

FIG. 7 illustrates one example of the wound roll 114 generated by the above-described system and method. The wound roll 114 is characterized by two banded regions 130a, 130b each having circumferential protrusions 132 (otherwise generated by presence of the corresponding strand 60a, 60b (FIG. 5)), and at least one un-banded or useful region 134 that is essentially free of circumferential protrusions or any winding-induced defects. It will be understood that where only a single strand 60 is employed, only a single one of the banded regions 130a or 130b will be generated; conversely, where a multiplicity of the strands 60 are provided, a corresponding number of the banded regions 130a, 130b will result. Regardless, the useful region(s) 134 represents a wound roll of the film 26 with minimal winding-induced defects. Subsequently, the wound roll 114 can be provided to a user whom then makes use of the film 26 from the useful region 134. Alternatively, the wound roll 114 can be subjected to further processing in which the banded region(s) 130a, 130b (and, in particular, the strand(s) 60 associated therewith) are removed.

The polymeric film winding and manufacturing methods and systems of the present application provide a marked improvement over conventional techniques in generating a wound roll of film with minimal or no winding-induced defects. Desired spacing between the outermost and immediately underlying wound layers of film are created by a separately provided strand, with this approach representing a low cost alternative to knurling. This is of particular benefit for certain films (e.g., low modulus, thin, optical grade films such as optical grade polypropylene films) that are not otherwise amenable to knurling or implementation of resin additives that might otherwise improve winding properties.

The winding systems and methods described herein can be enhanced with additional components or steps. In some embodiments, a pack or contact roll(s) is employed in conjunction with the wound film (both low and high modulus films). As a

point of reference, use of the pack or contact roll(s) is generally referred to as contact rolling, and allows the winding to occur with very low winding spindle tensions or torques because the contact roll(s) assist in forcing out excess air from between consecutively wound layers. This, in turn, can enhance layer-to-layer stability in the wound roll.

- 5 Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes can be made in form and detail without departing from the spirit and scope of the present invention.

What is claimed is:

1. A method of winding a polymeric film, the method comprising:
providing a length of polymeric film;
providing at least one small diameter strand apart from a polymeric film;
5 simultaneously winding the film and the strand about a cylinder to form a wound roll having successively wound layers of film with the strand continuously interposed between the successively wound layers of film;
wherein the strand establishes a gap between an outermost wound layer of film and an immediately underlying wound layer of film.
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2. The method of claim 1, wherein the film and the strand are continuously wound about the cylinder and the strand continuously establishes the gap between the outermost and immediately underlying wound layers of film.
- 15 3. The method of claim 1, wherein the strand establishes an air gap between the outermost and immediately underlying wound layers of film during winding.
4. The method of claim 1, wherein the film defines an unwound segment leading to the outermost wound layer such that relative to the cylinder, a wind interface is established
20 at a transition of the film from the unwound segment to the outermost wound layer, and further wherein simultaneously winding the film and the strand includes:
changing a lateral position of the strand relative to a width of the film at the wind interface.
- 25 5. The method of claim 4, wherein changing a lateral position of the strand includes:
moving the strand laterally at a point upstream of the wind interface.
6. The method of claim 5, wherein changing a lateral position of the strand further includes:
30 oscillating the strand back-and-forth upstream of the wind interface.

7. The method of claim 6, wherein with continuous winding of the film and the strand, a lateral position of the strand relative to an edge of the roll at the wind interface continuously changes.

5 8. The method of claim 6, wherein a distance of lateral oscillation of the strand relative to the wind interface is not more than 10 percent of a width of the film.

9. The method of claim 6, wherein a distance of lateral oscillation of the strand relative to the wind interface is not more than 6 inches.

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10. The method of claim 1, further comprising:
providing a plurality of small diameter strands apart from the film;
discretely positioning the plurality of strands relative to a width of the film; and
simultaneously winding the film and the plurality of strands about the cylinder.

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11. The method of claim 10, wherein a first one of the strands is positioned adjacent a first edge of the film and a second one of the strands is positioned adjacent a second, opposed edge of the film.

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12. The method of claim 10, further comprising:
continuously changing a lateral position of each of the strands relative to the film at a wind interface of the cylinder during continuous winding of the film and the strands.

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13. The method of claim 12, wherein continuously changing a lateral position of the strands includes simultaneously oscillating a lateral position of each of the strands relative to the film at the wind interface.

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14. The method of claim 1, wherein the strand has a major dimension that is at least 100 times less than a width of the film.

15. The method of claim 1, wherein the strand is a monofilament material.

16. The method of claim 1, wherein the strand is a multifilament material.

17. The method of claim 1, wherein the strand is a yarn material.

5 18. The method of claim 1, wherein the film is a polyolefin optical film.

19. The method of claim 18, wherein the film is an optical grade film.

20. The method of claim 1, wherein the film is a low modulus polypropylene film.

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21. The method of claim 1, wherein the film has a thickness of less than 25 microns.

22. The method of claim 1, wherein the film is a simultaneous biaxially stretched polyolefin film.

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23. The method of claim 1, wherein providing a length of film includes:
continuously supplying an extruded film from an extruder to the cylinder.

24. A system for winding a polymeric film, the system comprising:

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a polymeric film supply device having an exit;

a winding device including a rotatable cylinder positioned to receive polymeric film from the film supply device such that a wind interface is defined relative to the cylinder; and
a film spacer supplying a continuous length of a small diameter strand to the wind interface;

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wherein the system is configured to simultaneously wind a polymeric film from the film supply device and a strand from the film spacer about the cylinder such that the strand is continuously interposed between successively wound layers of film.

25. The method of claim 24, wherein the film spacer includes:

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a source of strand material; and

an oscillation device for moving the strand material laterally relative to the cylinder.

26. The method of claim 24, wherein the film spacer further includes:
a plurality of small diameter strands discretely positioned relative to a width of the cylinder.

- 5 27. The method of claim 24, wherein the polymeric film supply device includes:
an extruder for extruding a film sheet from a resin;
wherein the extruder is located in-line with the winding device and the film spacer is
positioned between the extruder and the winding device.

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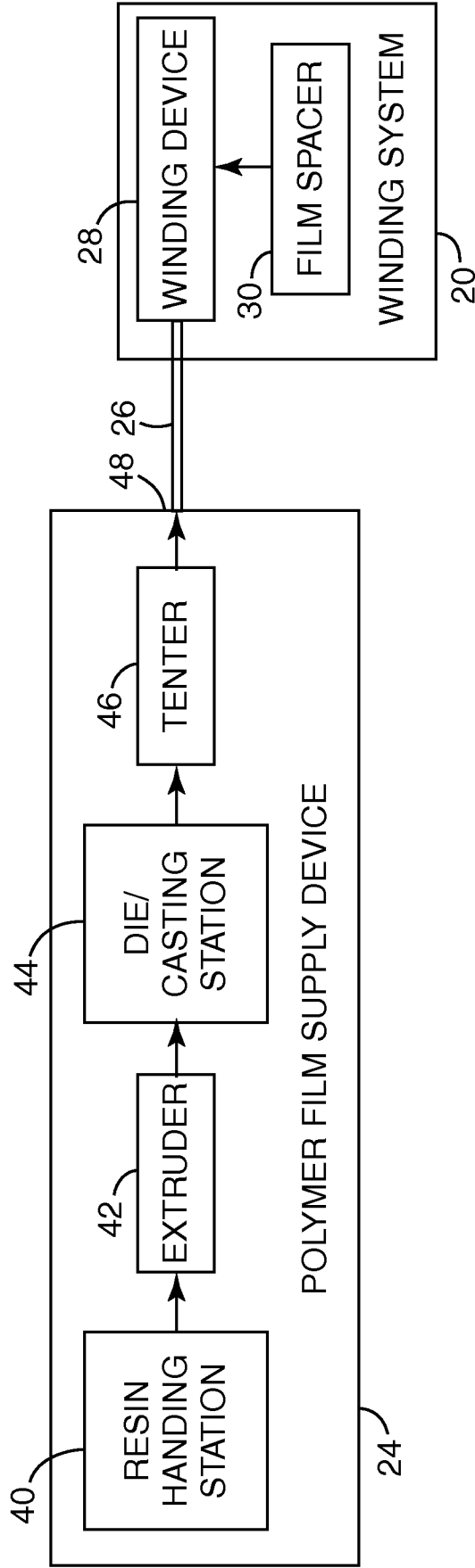


Fig. 1

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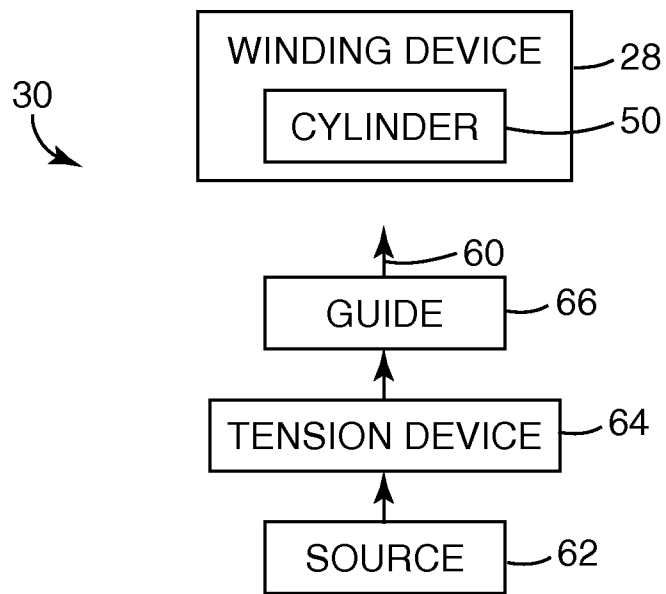


Fig. 2A

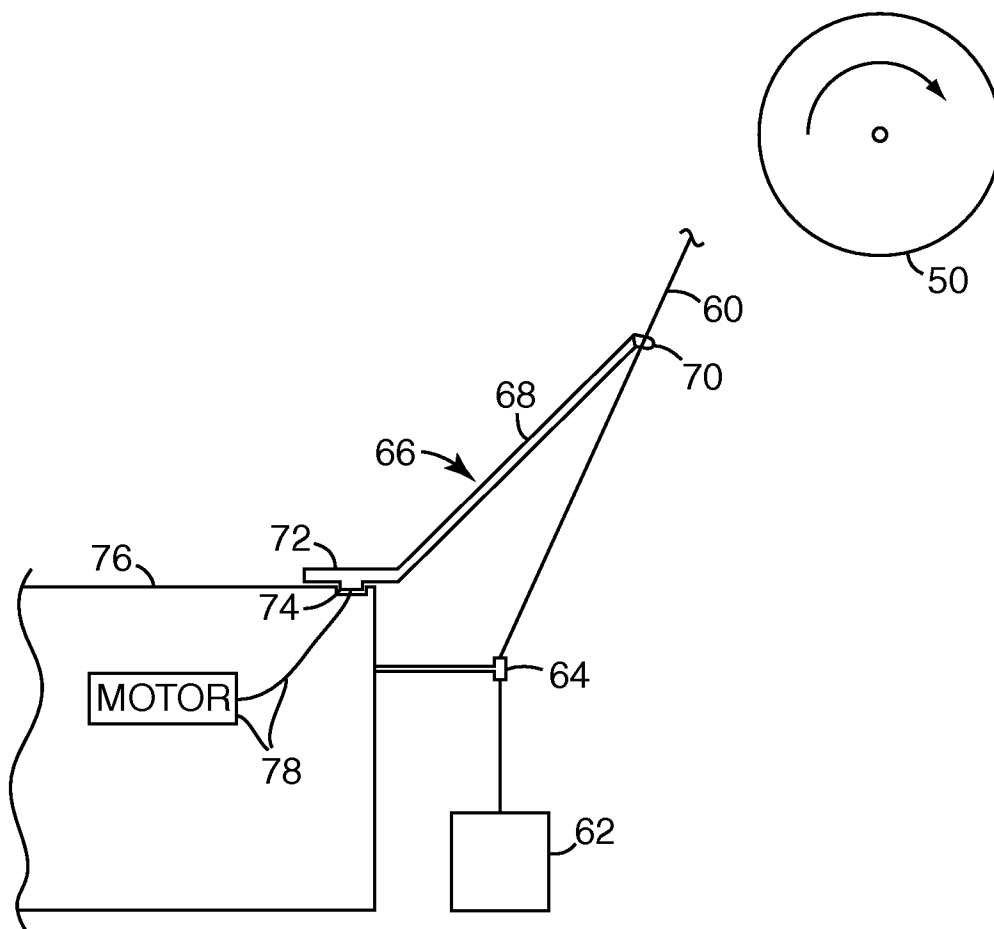


Fig. 2B

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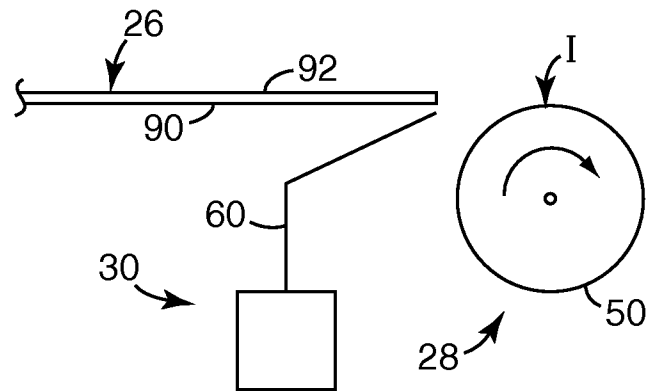


Fig. 3A

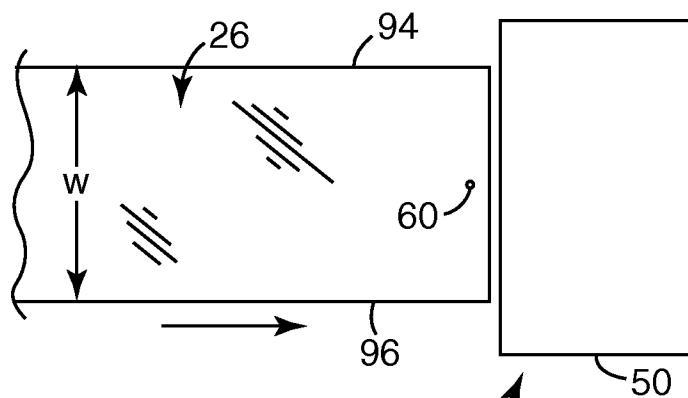


Fig. 3B

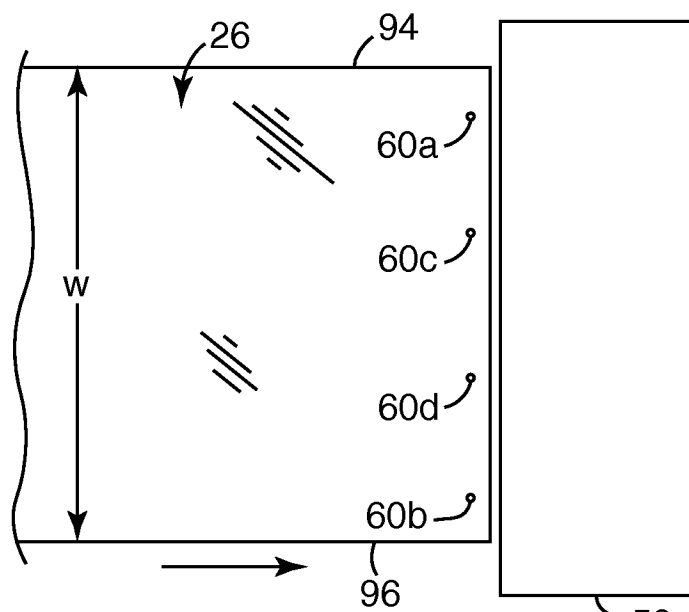
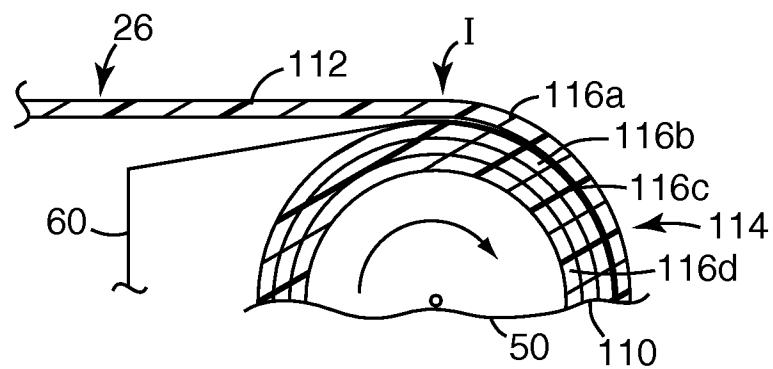
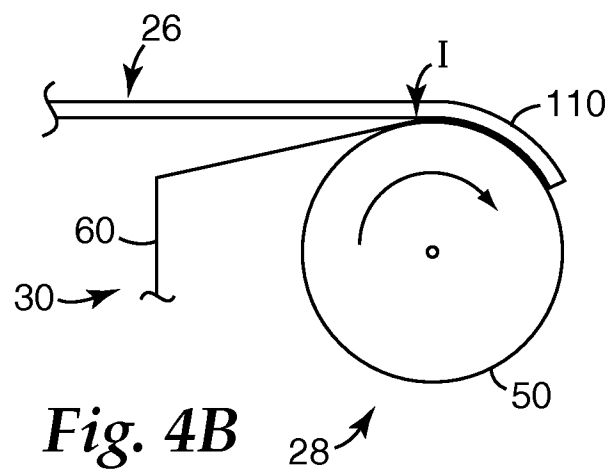
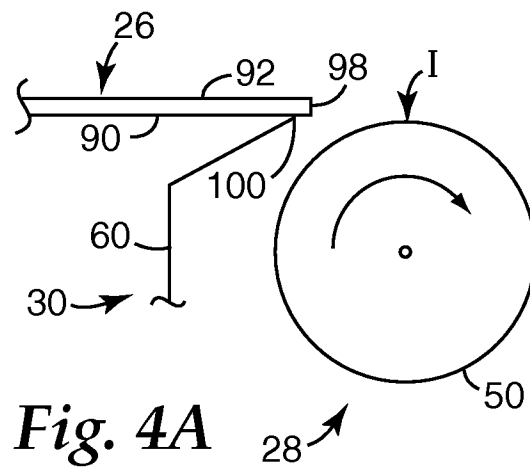
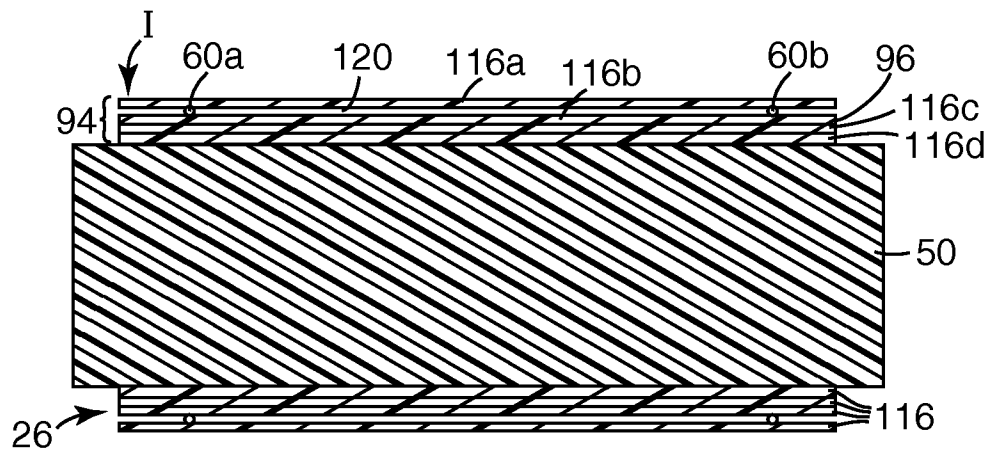
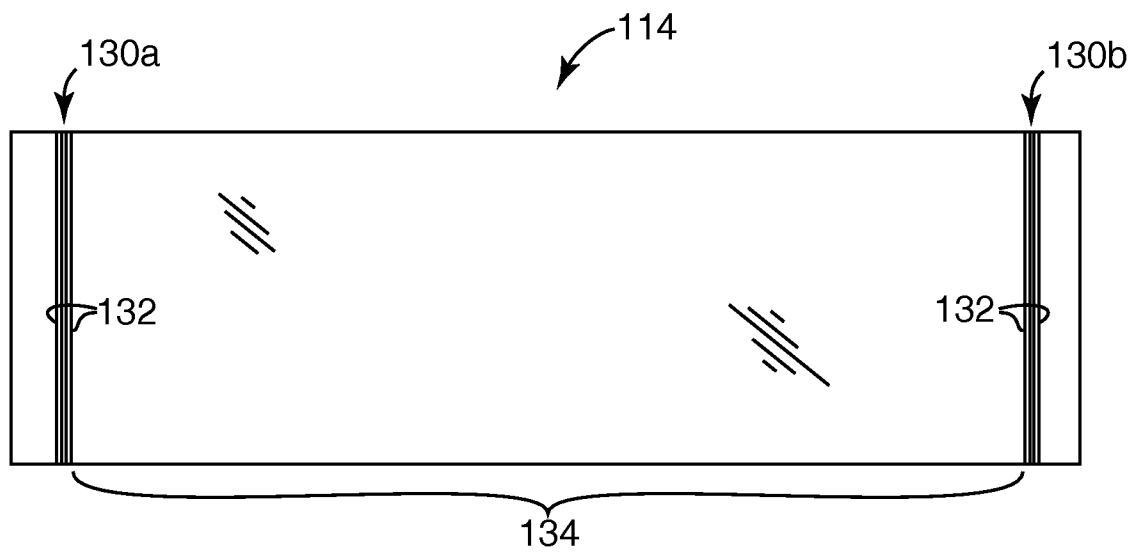


Fig. 3C

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*Fig. 5**Fig. 7*

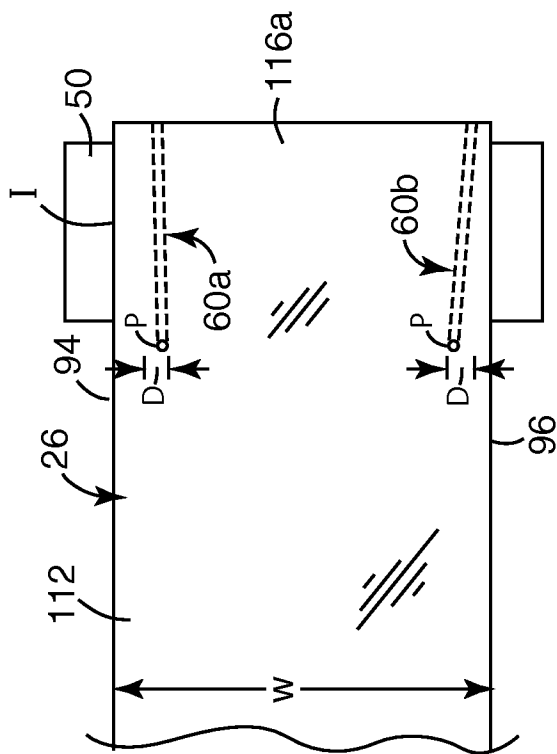


Fig. 6A

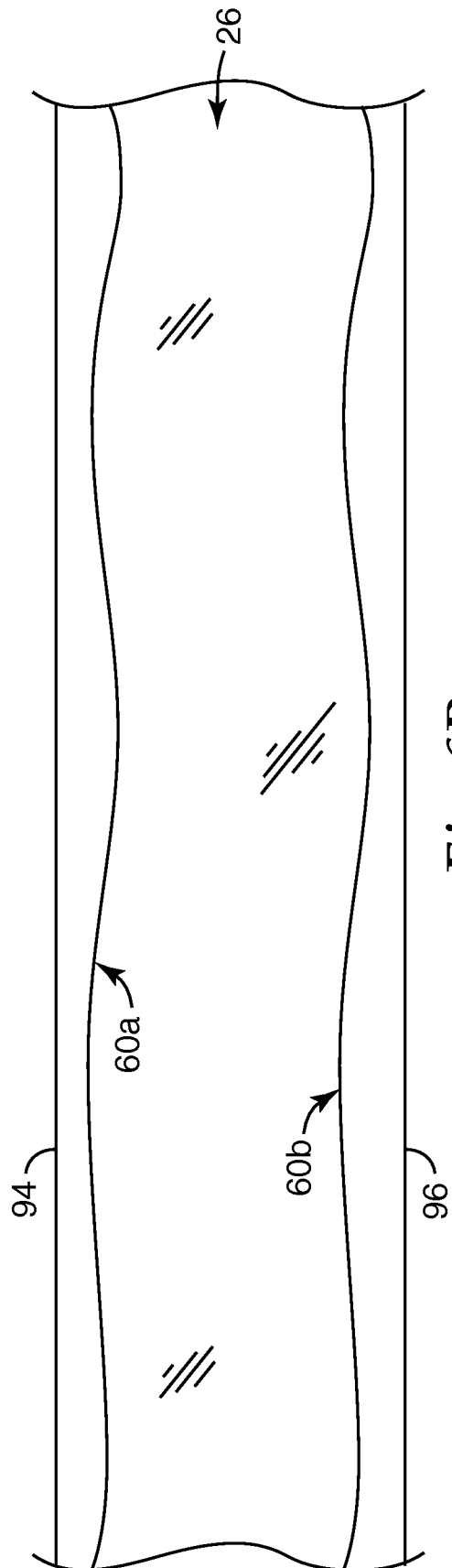


Fig. 6B

A. CLASSIFICATION OF SUBJECT MATTER***B65H 18/00(2006.01)i***

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)

IPC 8 (B65H 18/00 B65H18/10 B65H 19/28 G02F 1/335)

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

Korean Utility models and applications for Utility models since 1975

Japanese Utility models and applications for Utility models since 1975

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

eKIPASS (KIPO internal)

Keywords : "film", "winding", "defect", "strand"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2004-196448 A (KYOWA LTD.) 15 JULY 2004 See Figure 1 and related descriptions	1-27
A	JP 2006-306027 A (KONICA MINOLTA OPTO INC.) 09 NOVEMBER 2006 See Figure 3 and related descriptions	1-27
A	JP 08175708 A (DIAFOIL CO LTD.) 09 JULY 1996 See Figure 3 and related descriptions	1-27
A	JP 09124199 A (TORAY IND INC.) 13 MAY 1997 See Figure 2 and related descriptions	1-27
A	JP 11059985 A (UNITIKA LTD.) 02 MARCH 1999 See Figure 1 and related descriptions	1-27



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

30 JULY 2008 (30.07.2008)

Date of mailing of the international search report

30 JULY 2008 (30.07.2008)

Name and mailing address of the ISA/KR

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JEONG JI Deok

Telephone No. 82-42-481-8420



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2008/062604

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