United States Patent [19]

Jennings et al.

[11] **3,718,288**

[45] **Feb. 27, 1973**

[54] **YARN PACKAGE**

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[73] Assignee: **E. I. du Pont de Nemours and Company**, Wilmington, Del.

[22] Filed: **March 31, 1971**

[21] Appl. No.: **130,036**

Related U.S. Application Data

[62] Division of Ser. No. 865,550, Oct. 13, 1969, Pat. No. 3,589,631.

[52] **U.S. Cl.**.....**242/178**, 242/43

[51] **Int. Cl.**.....**B65h 55/04**, B65h 54/28

[58] **Field of Search**.....242/178, 174, 175, 176, 177, 242/159, 43, 18.1

[56] **References Cited**

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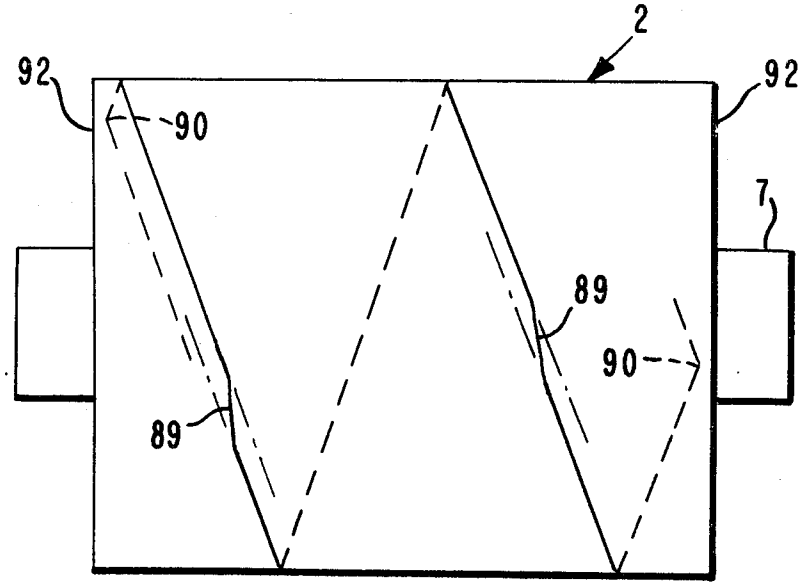
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Primary Examiner—Stanley N. Gilreath
Attorney—Howard P. West, Jr.

[57] **ABSTRACT**

A process for winding yarn into a cylindrical-bodied substantially straight-ended package wherein the yarn is traverse wound in layers of helical coils on a bobbin by traversing the yarn axially through successive stroke lengths in repeating time periods to form a package and wherein two successive stroke lengths form a traverse cycle. The improvement includes the steps of progressively decreasing the stroke length to a first value then increasing the stroke length to a second value within 50 percent of the duration of each of the time periods, while varying the helix angle at least twice during a preponderance of the traverse cycles. The winding apparatus for accomplishing this includes a divided barrel cam with sliding portions that are moved axially in concert in a programmed sequence to disperse the yarn laydown at the reversals. Yarn packages of improved formation and stability are wound using the process and apparatus of this invention. The packages are formed of a plurality of layers of helical coils, wherein each coil includes successive helical and reversal portions and are characterized by having at least two inflections in the helical portions of a preponderance of the coils.

7 Claims, 33 Drawing Figures



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SHEET 1 OF 5

FIG. 1

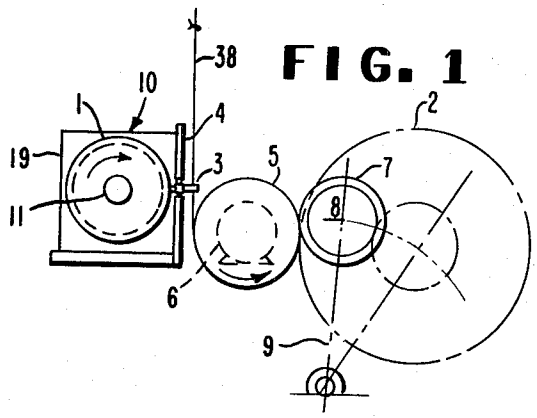


FIG. 3

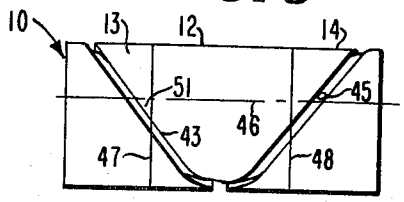


FIG. 4

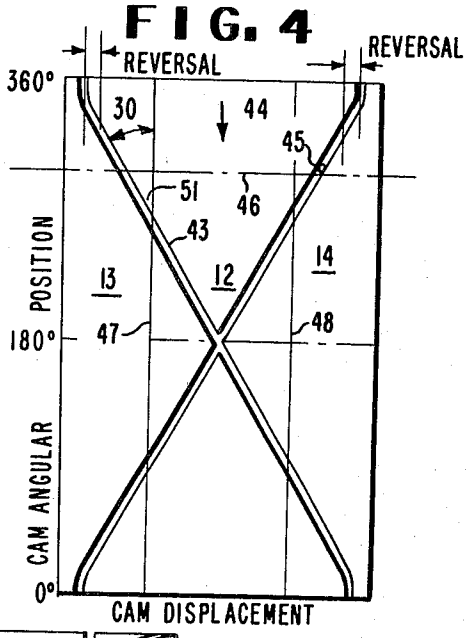


FIG. 11

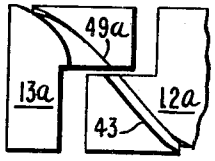


FIG. 12

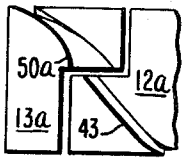


FIG. 5

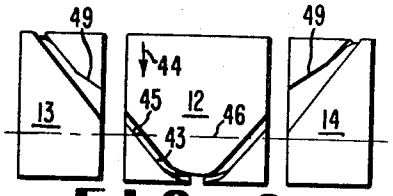


FIG. 6

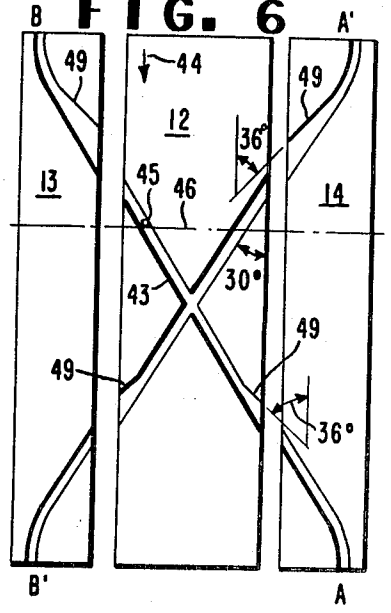


FIG. 7

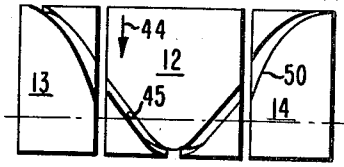
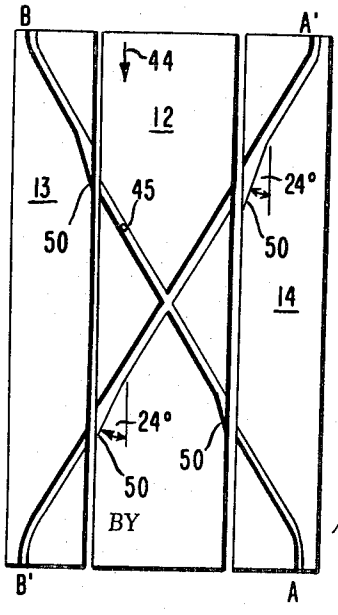


FIG. 8



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FIG. 2A

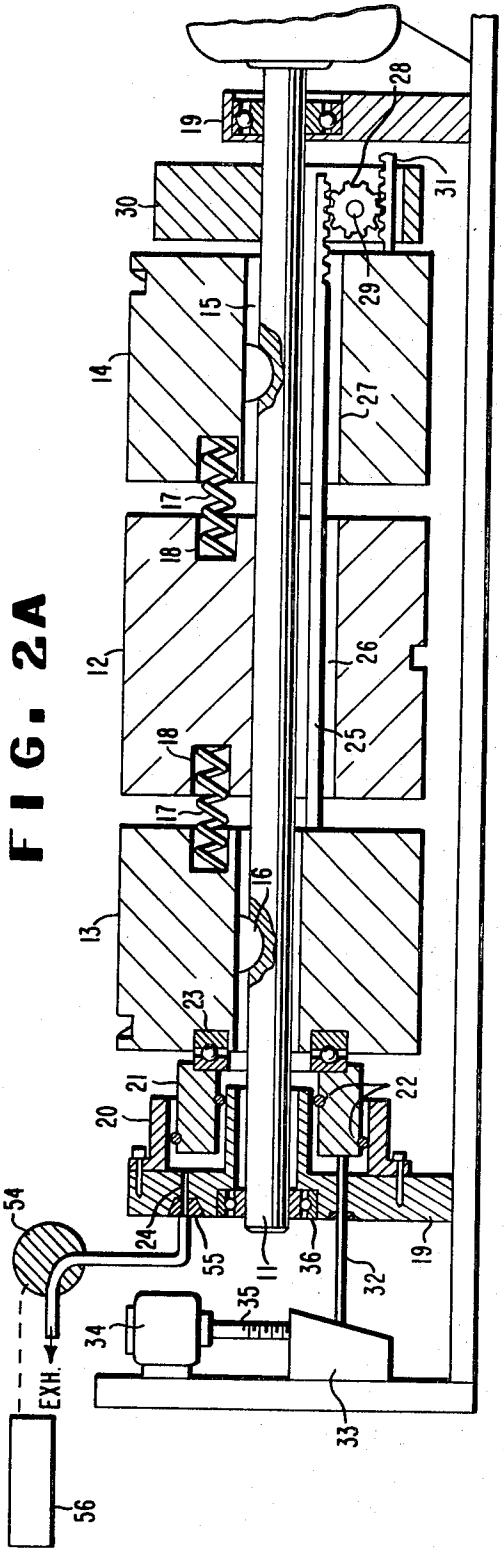
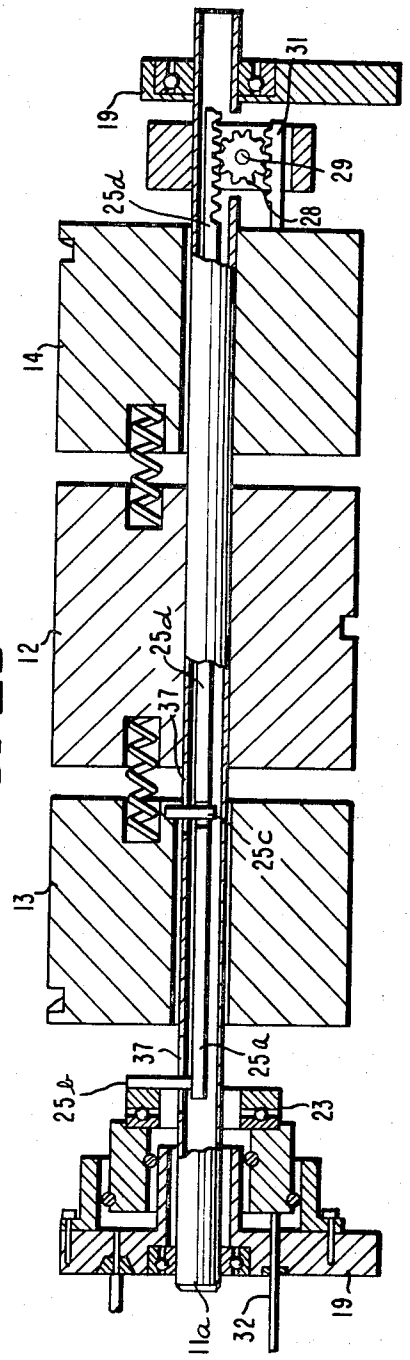


FIG. 2B



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FIG. 9

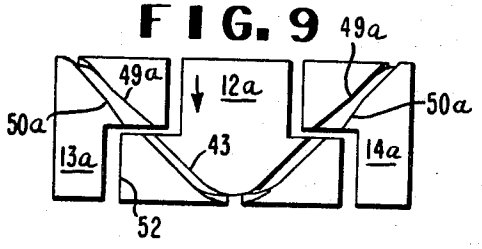


FIG. 13

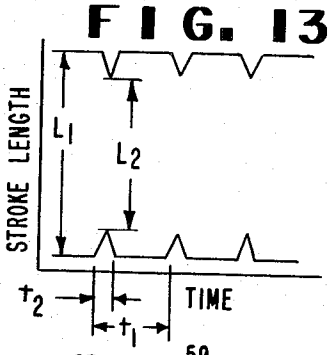


FIG. 14

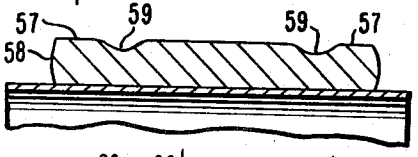


FIG. 10

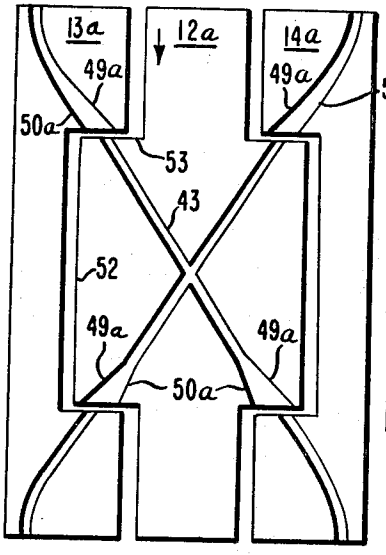


FIG. 15

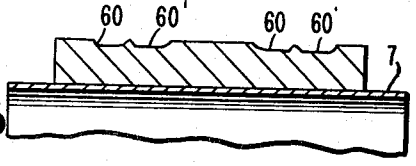


FIG. 16

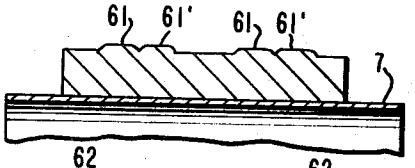


FIG. 17

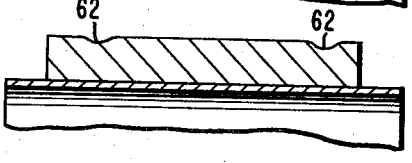
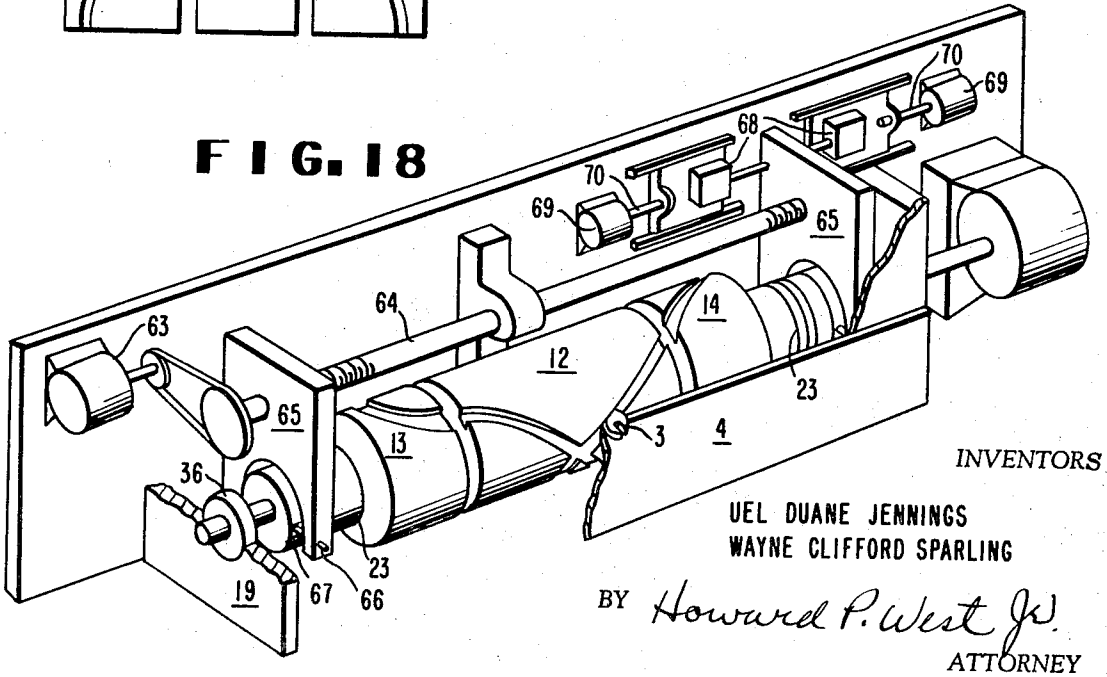


FIG. 18



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FIG. 20A

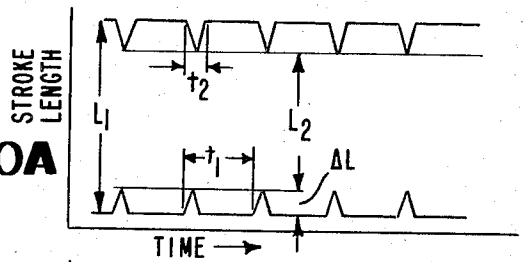


FIG. 20B1

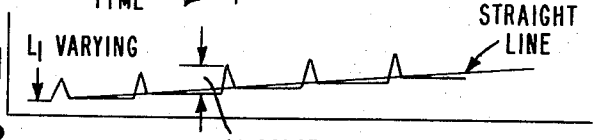


FIG. 20B2

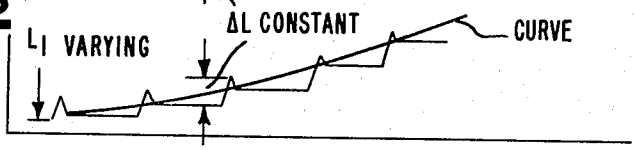


FIG. 20C1

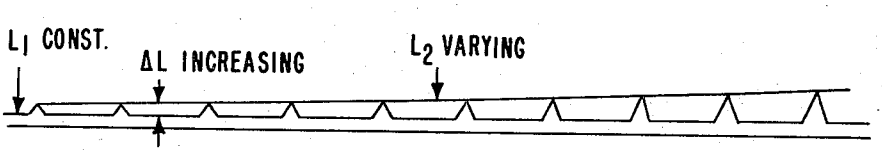


FIG. 20C2



FIG. 20C3

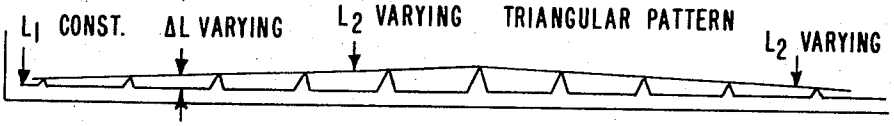


FIG. 20C4

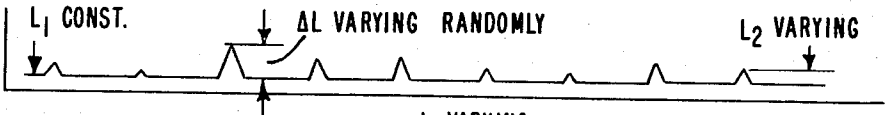
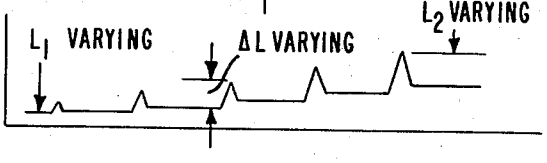


FIG. 20D



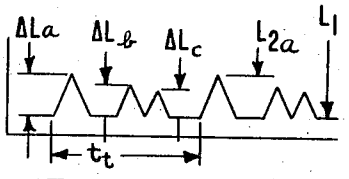
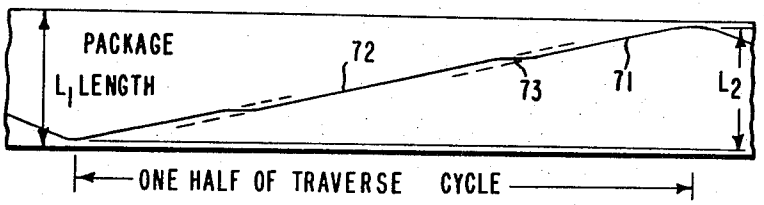


FIG. 20E

FIG. 19



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FIG. 21

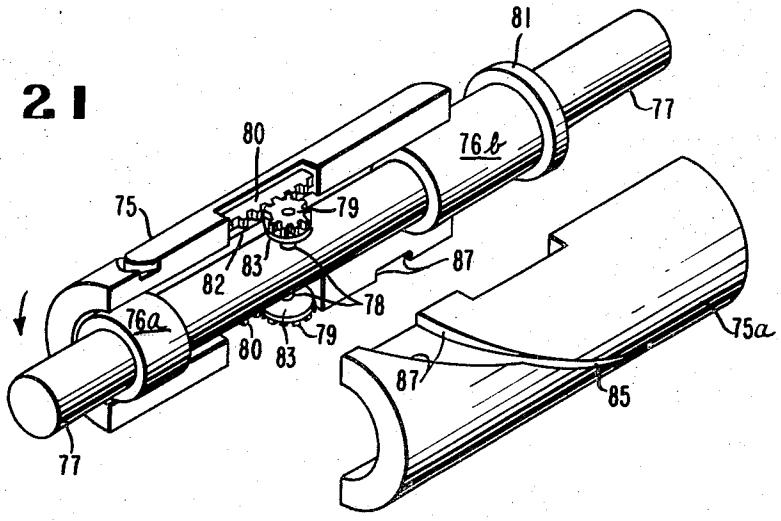


FIG. 22

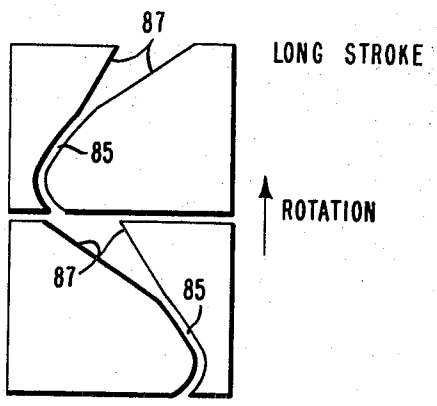
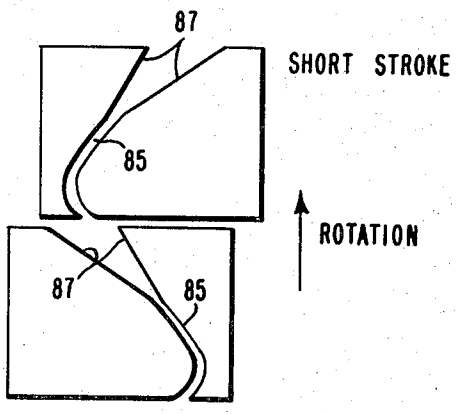


FIG. 23



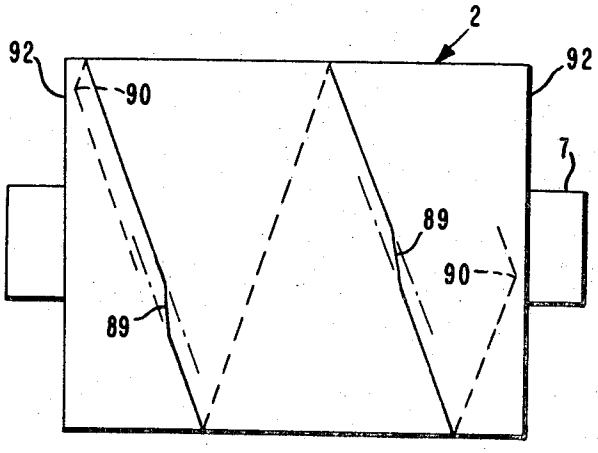


FIG. 24

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YARN PACKAGE

CROSS REFERENCE TO RELATED APPLICATION

This is a division of application Ser. No. 865,550, filed Oct. 13, 1969 now U.S. Pat. No. 3,589,631.

BACKGROUND OF THE INVENTION

This invention relates to the cross-winding of yarns and more particularly to the winding of cylindrical yarn packages with improved formation and stability. Such packages are commonly formed by windups employing a surface drive. The drive roll is operated at a constant speed thus maintaining a constant surface velocity of the driven package despite the growth of the package as the filamentous material is wound thereon. A cam-actuated reciprocating traverse guide may be used to lay the yarn onto the bobbin in layers of helical coils either directly or by means of a print roll.

Currently used high-speed winding techniques do not give completely satisfactory package formation when attempts are made to achieve increased package size; i.e., an increase in package defects which include bulge, spiral fans, overthrown ends, and high shoulders are generally noted. All of these appear to be related in some way to yarn laydown near the ends of the cylindrical yarn package.

In the past, attempts have been made to improve yarn distribution at and near the package ends, such as by superimposing an axial reciprocation on the primary traverse stroke or by changing the length of the stroke cyclically by mechanical means with essentially no change in yarn helix angle to spread out or disperse the yarn laydown at the package ends or shoulders. These and other approaches provide very limited dispersion patterns.

SUMMARY OF THE INVENTION

According to the present invention there is provided a method of winding a surface-driven package which comprises traversing yarn through successive stroke lengths wherein two successive stroke lengths form a traverse cycle and each stroke length is essentially equal to initial package length in a time-program having a plurality of repeating finite first periods each of which include a shorter second period in which there occurs a progressive shortening of the traverse stroke length to a first value less than the initial stroke length followed by a substantially instantaneous reversal of the shortening effect and a progressive increase in the stroke to a second value at which it stabilizes for the remainder of each first period. The duration of a second period never exceeds one-half the duration of a first period and in which winding method, exclusive of the reversals, the helix angle of the wound yarn shows a variation at least twice in a preponderance of the coils.

The apparatus according to the present invention includes a barrel cam with parallel aligned guide rails and a cam follower-yarn guide between the rails, in driven engagement with the cam for traversing the yarn. The cam is divided with sliding portions that are moved axially in concert in a programmed sequence to disperse the yarn laydown at the reversals. In one embodiment the barrel cam is divided into a central portion and a pair of end portions supported by a shaft and rotatable therewith. The end portions are axially slidable on the shaft. The end portions have reversal cam grooves in their surface, the inwardly facing terminal ends of which are generally aligned with respective essentially helical grooves of the central cam portion. Means are provided for axially moving the end cam portions in concert toward and away from the central cam portion out of alignment with the grooves of the central portion in a preselected timed sequence of events.

In another embodiment the cam is cut in half lengthwise on parting lines which include the axis of rotation of the cam. The cam halves are slidably mounted on the traverse shaft and spaced to permit each cam half to move axially relative to the other.

According to this invention unique packages are formed of a plurality of layers of helical coils wherein each coil includes successive helical and reversal portions. There are at least two inflections in the helical portions of each of a preponderance of the coils in the package.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic, end-elevational view of a type of windup apparatus in which the present invention may be used.

FIG. 2A is a longitudinal cross-section of one embodiment of segmented barrel cam assembly of this invention showing cam segments and means for actuating them.

FIG. 2B is similar to FIG. 2A except that it shows a different means for actuating the cam segments.

FIG. 3 is a side elevational view of a three-piece barrel cam showing the separate portions.

FIG. 4 is a developed view of the outer surface of the cam of FIG. 3 showing cam grooves in their aligned condition.

FIG. 5 is a side-elevational view of a three-piece barrel cam showing end portions widely separated from the center portion.

FIG. 6 is a developed view of the cam of FIG. 5 showing a lack of alignment in the cam grooves of the various portions of the cam and angled surfaces for obtaining alignment.

Fig. 7 is a side-elevational view of the three-piece cam of FIG. 5 showing end portions closed upon the center portion.

FIG. 8 is a developed view of the cam of FIG. 7 showing a lack of alignment in the cam grooves but in the opposite direction from the showing in FIG. 6; this view also includes angled surfaces for obtaining alignment.

FIG. 9 is a side-elevational view of a three-piece barrel cam having a parting line which extends parallel to the cam axis of revolution.

FIG. 10 is a developed view of the cam of FIG. 9.

FIG. 11 is a fragmentary side-elevational view of the cam of FIG. 9 showing one end portion separated from the center portion.

FIG. 12 is a fragmentary side-elevational view of the cam of FIG. 9 showing one end portion closed upon the center portion.

FIG. 13 is a plot of traversing mechanism stroke length as ordinate VS time as abscissa showing several preferred programs of stroke length variation useful in this invention.

FIG. 14 is a partial cross-sectional view representative of a yarn package of the prior art showing defects.

FIG. 15 is a partial cross-sectional view representative of a yarn package as wound by the cam as shown in FIG. 5.

FIG. 16 is a partial cross-sectional view representative of a yarn package as wound by the cam as shown in FIG. 7.

FIG. 17 is a partial cross-sectional view representative of a yarn package in which winding is carried out both with cam end portions alternately separated (FIG. 15) and closed (FIG. 16).

FIG. 18 is an isometric view of a traverse mechanism which employs a motor and screw arrangement for moving parts of the barrel cam.

FIG. 19 is a developed view of a yarn package.

FIGS. 20A–20E show diagrammatic representations of traverse programs used in this invention.

FIGS. 21–23 illustrate a two piece cam and developed views for long and short stroke positions of the cam.

FIG. 24 is a schematic illustration of a yarn package showing inflections in the helical portions of the windings.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

The apparatus of this invention may be used in a windup of the type shown in FIG. 1 which comprises a cam assembly 10, a fixed drive roll 5 coupled to a motor 6, a bobbin 7 on a support 8 which is carried on a pivoted arm 9 which in turn is adapted to urge the bobbin 7 or the growing package 2 against the drive roll 5. A typical cam apparatus 10 of the prior art generally comprises a barrel cam 1 on a shaft 11 mounted for rotation in bearings in fixed pedestals 19 to which are secured spaced, parallel guide rails 4 which hold a cam follower-traverse guide 3 in engagement with a cam groove in the barrel cam 1.

Referring to FIG. 2A, one embodiment of the cam assembly of this invention generally comprises a central cam portion 12 and axially movable cam end portions 13, 14 carried on a shaft 11. The central cam portion is fixed to the shaft (e.g., by a press-fit) while the end portions 13, 14 are keyed for rotation with the shaft by means of keys 16 and keyseats 15 and are slidable axially. Both of the end portions 13, 14 are urged away from the central portion by means of coil springs 17 which engage recesses 18. The separation of the left cam end portion 13 relative to the central cam portion 12 is limited by means of the annular piston 21-cylinder 20 assembly shown at the left on the fixed pedestal 19 which also carries a ball bearing 36 for supporting shaft 11. Sealing of the piston 21 is effected by means of elastomeric rings 22. The righthand end of the piston 21 abuts a thrust bearing 23, the opposite side of which lies against the end face of the cam end portion 13. A port 24 in the pedestal 19 serves to admit pressurized air via valve 54 (from a source not shown) to the cylinder 20 thus making it possible to move the piston 21, the bearing 23 and the cam end portion 13 to the right against the urging of the springs 17. The cam end portion 14 on the right-hand end of the assembly is actuable by the same piston 21 and cylinder 20 and a mechanism generally comprising a long bar 25, a gear 28 and a rack 31. The bar extends parallel to the shaft 11 from cam end portion 13 being slidable endwise through aligned openings 26, 27 in cam portion 12 and end portion 14. At its right end the bar 25 has rack teeth which engage the small gear 28 which is rotatably mounted on a shaft 29, both being located in a slotted aperture in disk 30 which is secured to the shaft 11 by a means not shown. The ends of shaft 29 are fixed in disk 30. Engaging the gear 28 on the side opposite from the bar 25 is a short toothed rack 31 which abuts the end face of cam end portion 14 thus being adapted to hold it against the urging of springs 17.

In another embodiment, shown in FIG. 2B, the arrangement is similar to that of FIG. 2A except that the shaft 11*a* is hollow and the bar 25*a* is situated inside the shaft, being provided with radial pins 25*b* 25*c* which extend outwardly, through axially aligned, elongated slots 37 in the shaft 11*a* to engage the thrust bearing 23 and cam end portion 13. Another bar 25*d* is in endwise abutment with the first bar 25*a* and is associated with a rack-pinion-rack mechanism as in the embodiment of FIG. 2A. The limit of outward displacement of the cam end portions 13, 14 relative to the center portion 12 is reached when the piston 21 bottoms in the cylinder 20, i.e., with air "off", the cam stroke then being called "normal." However, an additional mechanism is provided (FIG. 2A) to permit alteration of the overall stroke of the cam assembly, comprising an axially slidable stop pin 32, a wedge 33, a screw 35 and a motor 34. If the cam stroke is to be shortened, the motor 34 is operated at a very blow speed and in a direction to drive the wedge 33 downward thus causing the pin 32 to move to the right where it either drives the piston 21 to the right or acts as a stop for leftward motion of the piston. Operating the motor in the reverse direction will, of course, withdraw the wedge, effectively lengthening the cam stroke. The motor and wedge may be operated continuously, effecting a gradual change in cam stroke length, or may be stopped at any intermediate position to hold the cam stroke constant at some value less than "normal" as will be discussed further, below.

Cam paths are best studied in a developed view, such as the one shown in FIG. 4, in which the outer cylindrical surface of the cam barrel of FIG. 3 is "unrolled" to a planar representation in order to show the true path of the entire cam groove 43. These developed views may also be viewed as a plot of cam displacement (abscissa) versus cam angular position (ordinate) and in FIG. 4 it may be seen, throughout most of the stroke of the cam, that the path follows a straight line, representative of a true helical path. The reversal portions will be seen to follow curving paths which may occupy some 40° to 60° or more of cam angular travel and which are generally designed to accommodate the accelerations incident to the reversal. In examining cam groove details, it should be kept in mind that the direction of motion of the cam (CW as viewed in FIG. 1) is such that the developed cam surface of FIG. 4 appears to move downward as shown by arrow 44; the cam follower 45 is restrained by guide rails and moves only from side-to-side along line 46.

In a typical barrel cam of about 4 inches diameter and 7 inches stroke, the straight line or helical path forms an angle of about 30° with a plane at right angles to the cam axis of revolution, the lead (advance per revolution) of the helix being about 7.15 inches. In an

embodiment of the present invention such a cam is divided into segments by cutting it into three separate portions along lines **47** and **48** (FIGS. **3** and **4**) about 1.6 inches from each reversal and in such a manner as to remove about 0.25 inch of material from the cut, leaving a gap between segments of that magnitude. In general, the line of separation will be called a discontinuity whether a gap is present or not. In an assembled condition, as previously described, in which the end portions of the cam are movable axially, with respect to the center, the cam follower will negotiate the discontinuity or 0.25 inch gap satisfactorily but any departure from that magnitude of gap (by moving the end portions) demands alterations in the part of the cam groove, called the "downstream" part, which the follower enters after having crossed the gap. Thus, with each of the end portions open to about 0.4 inch axial gap (i.e., maximum cam stroke, piston **21** bottomed in cylinder **20**) the confronting portions of the groove will no longer be in alignment and the side or wall of the cam groove first to encounter the follower **45** as it leaves the gap and reenters the section of the cam groove on the "downstream" side must be relieved at the interconnecting portion as shown by line **49** in FIGS. **5** and **6** which is helical but is disposed at an angle of about 36° (as compared to 30° in the remainder of the groove). In the end portions **13**, **14**, this relief or this helix terminates at the point or just short of the point at which the 30° helix would have terminated, namely, near the beginning of the curving reversal portion of the cam. In any given traverse cycle this cam will go through two revolutions, thus the follower will negotiate a discontinuity at four places and the same relief must be provided at these sites all of which are identified by lines **49** and all of which are machined at an angle of about 36°. Because of the varying pressure angle (from 30° to 36°) the cam follower will be subject to a slight increase in velocity, the effect of which will be discussed below.

If the cam portions **13**, **14** are now moved to a near-zero gap condition or "closed" as shown generally in FIGS. **7** and **8** (by means of the piston **21** and cylinder **20**, air "on") a groove misalignment will again be present and the lower side wall of the cam groove will now be the first to encounter the follower **45** as it negotiates the discontinuity, crossing to the "-downstream" side. The lower part of the cam groove wall is relieved at four portions, each shown by a line **50** which is helical but is disposed at an angle of about 24° again extending to a point at the beginning of the curving reversal or slightly short of that point at the two places where it occurs in the end portions **13**, **14** and duplicated both as to angle and as to extent (measured along the stroke) in the two places of occurrence in the central cam portion **12**. It will be realized that the separately described features of FIGS. **5**, **6**, **7** and **8** are all combined into a single cam.

The use of an axial gap between cam portions may lead to difficulty at cam startup because the follower may not negotiate the gap properly if it is not up to velocity as it encounters the gap. Even if the cam is up to speed, difficulty might also be experienced because of a loss in velocity of the cam follower (due, for example, to follower-guide rail friction, yarn tension, windage, etc.). In either case, there is a risk that the follower may not reenter the groove of the cam properly but may "hang up" on a sharp corner **51** such as shown in FIGS. **3**, **4** and be severely damaged. Such a possibility is eliminated in a preferred embodiment of cam shown in FIGS. **9**, **10**, called an overlapping cam, which comprises a central portion **12***a*, and end portions **13***a*, **14***a* which are separated by stepped dividing lines **52** in which the surfaces **53** each intersect a part of the cam groove **43**, being aligned parallel to the axis of rotation of the cam barrel. Use of such a construction means that there will be no actual gap or separation along the cam groove. There will be discontinuity in the cam groove, however, which is taken into account by cutting a relief on the "downstream" side walls as shown at line **49***a* in FIG. **11** (cam portions "open") and as shown at line **50***a* in FIG. **12** (cam portions "-closed") which appear at three other places on any given cam groove, as shown in FIG. **10**. These parts of the cam groove, depicted by lines **49***a* and **50***a*, may be helical, as in the first embodiment, and are cut at like angle (say about 24° and 36°) relative to a plane at right angles to the cam axis of rotation to the same extend (measured along the stroke).

In operating the traverse mechanism the motions of the end portions **13**, **14** of the cams may be programmed as shown in the plot of stroke length L versus time shown in FIG. **13** in which L_1 is the maximum stroke length and L_2 is the minimum stroke length (air "on", cam portions "closed"), t_1 is the cycle time, in seconds, and t_2 (which is part of time t_1) is the duration of a single period in which the cam end portions are driven "in" and "out" again. Under practical conditions of winding the following values may be used:

L_2 equals 0.8 to 0.98 L_1, preferably about 0.85 to 0.9 L_1

t_2 equals 0.1 to 0.5 t_1, preferably about 0.25 t_1

t_1 equals 2 to 25 seconds, preferably 2 to 5.

Successive periods t, need not necessarily be of equal duration. In operating a windup and a traverse mechanism as described above, advancing yarn **38** is carried through the traversing guide **3**, around the drive roll **5** and is strung-up and deposited on the bobbin **7** while the traversing mechanism is cycled. For example, using the program shown in FIG. **13**, the timing device **56** functions continuously operating the valve **54** through which air is admitted to the cylinder **20** (air "on") via the conduit and throttling orifice **55** which regulates the rate at which air enters and leaves the cylinder, which in turn regulates the rate of axial movement of the piston **21** and cams. Air is permitted to flow to the cylinder for time ½ t_2 at the end of which time period the traverse stroke reaches a first value (length L_2) but only for an instant whereupon the timing device **56** actuates the three-way valve **54**, shutting off the air supply and connecting the cylinder to the exhaust port. The throttling orifice **55** now regulates the out-flow of air from the cylinder, which occurs in a period of about ½ t_2, during which the traverse stroke returns to a value L_1, in this case the maximum traverse stroke length. The winding continues at the maximum traverse stroke L_1 for a time period (t_1–t_2) until the timing device again actuates valve **54** to admit air to the cylinder after which the cycle is repeated throughout the winding of the package.

In the discussion of the helical portions of the cam grooves it will be recalled that most of the central cam portion was out at a constant angle (e.g., 30°) while certain of the reliefs were cut at different angles (e.g., 24° and 36°) both in the central cam portion and in the end portions short of the reversals. Since the angles of the cam differ, it follows that the velocity of the cam follower-traverse guide will differ each time the follower is driven by a different part of the cam. Thus, using the 30° part of the cam as a basis of comparison, at low cam angles (24°) the rate (velocity) of traverse will be lower and at high cam angles (36°) the rate (velocity) of traverse will be higher. Generally speaking, this means that at low cam angles (24°) more yarn will be deposited on the package per unit length of package measured axially thereof than when in the 30° part of the cam, and at high cam angles (36°) less yarn per unit length of package will be deposited than when in the 30° part of the cam. The foregoing effect is illustrated diagrammatically in FIGS. **15** and **16**, both of which show partial cross-sections of packages.

Referring to FIG. **15** which is related to the developed cam profile of FIG. **6**, and further taking a single revolution of the cam from point A to point B (FIG. **6**), the effect of changing rate of deposition of the yarn on the package will be seen in FIG. **15** where the high velocity of traverse of the reliefs **49** results in the deposition of less yarn on part of the packages as shown by the two dips **60**, the vertical dimensions of which are exaggerated for purposes of illustration. Similarly, going one additional revolution from B' A', dips **60'** will be produced. Thus for one cycle of the traverse (two revolutions of the cam) it will be seen that the combined dips **60** and **60'** are spaced about equally, measured inward from the ends of the package.

Now referring to FIG. **16**, similarly related to the cam profile of FIG. **8** and again in a single revolution from A to B, the effect of the lower velocity of traverse of the relief **50** (more yarn deposited) is shown by raised bands **61** (height exaggerated), and from B' to A' by hands **61'** which may be seen to be equally spaced inward from the ends of the package, however, the spacing from the end of the package to the end of a given band **61** or **61'** will be seen to be greater than the corresponding spacing to the dips **60** or **60'** (FIG. **15**) by reason of the fact that a short cam stroke (L_2) condition prevails in producing the "band" laydown profile of FIG. **16** as compared to the full stroke (L_1) or "dip" laydown of FIG. **15**.

While the foregoing discussion assumes that the cam end portions are static, it will be recalled, in actual winding, that the cam end portions are being moved axially during part of the time (t_2). The net result is that the bands **61** become superimposed on the dips **60** more-or-less in successive wraps on the package tending to fill the latter and produce a "level" package with the exception that the time period t_2 (short stroke L_2) during which bands **61** may be wound is half as long or less than half as long as the time period t_1 (full stroke L_1) during which dips **60** are wound; thus, the actual combined profile of a package might appear as shown in FIG. **17** where slight dips **62** could occur except for a further leveling effect described below.

In prior art type traverse programs an inevitable decrease in velocity of traverse occurs at the ends of the stroke this being necessary in the interest of avoiding excessive follower accelerations and excessive loadings in the reversals. Concomitant with the reduction in traverse velocity is the laydown of a slightly greater amount of yarn per unit length of package giving rise to the well-known shoulders **57** at each end of the package shown in cross-section in FIG. **14**. These are often accompanied by bulges **58** and dips **59**. In the present invention, however, the reversals, during part of the time (t_2), are moved inwardly from the ends of the package in successive cycles thus tending to subtract yarn from the shoulders **57** and cause its deposit in the dips **59** thereby tending to "level" the profile of the package as seen in cross-section. Ordinarily, however, more shortening of the traverse stroke would not eliminate the shoulders completely but would simply move the now-smaller shoulders inward from the ends of the package; further in accordance with the present invention, however, the dip **62** (FIG. **17**) is available to receive some of the "shoulder yarn" and does so, thereby resulting in a substantially complete leveling of the package.

It will be realized, referring to the embodiments of FIG. **2A**, **2B**, that an additional stop mechanism (not shown) of the same general type as the pin **32** and its associated wedge and drive could be employed to stop the piston in the inward direction at a position short of that at which the cam end portions **13**, **14** abut the central portion **12** (thus making it possible to limit the stroke length L_2).

In yet another embodiment, as shown in FIG. **18**, the position of the cam end portions and control of the limits of their motions is effected by means of a reversible motor **63** and driven screw **64** engaged with traveling yokes **65** which are joined by means of pins **66** to thrust plates **67** which are in abutment with thrust bearings **23** and hence cam end portions **13**, **14**. The extent of end-wise motion of the cam is controlled by slidable electrical limit switches **68** (which reverse the motor **63**) each of which switches may be independently slidable to provide long or short strokes of the mechanism, for example, by means of individual reversible motor **69** and screws **70** drives. Cycling of this apparatus is controlled from a timing device (now shown). The illustrated apparatus may be employed to effect a variety of winding programs such as those shown in FIGS. **20A**, **20B**, **20C**, **20D** and **20E** to be described. In this discussion the term Δ L is used for convenience and is the difference between the greatest traverse stroke length and the smallest stroke length in a given time period t_1 measured at one end of the package or:

$$\Delta L = \tfrac{1}{2}(L_1 - L_2)$$

Referring to FIGS. **20A** to D:

20A: stroke shortened from L_1 to L_2 periodically at time periods t_1; L_1 and L_2 are each constant, thus Δ L is constant.

20B: stroke L_1 is altered while ΔL remains constant. This program as well as that of **20D** makes it possible to taper the end of a package or to compensate for a propensity of the package to bulge at the ends; a number of variations are possible; viz:

20B(1): L_1 changing by equal increments in successive equal time periods t_1 or a straight-line program of decrease or increase in package length.

20B(2): L_1 changing by unequal increments in successive equal time periods t_1 or a curving program of change in package length which could follow a concave or a convex path.

20C: ΔL is varying at intervals t_1 in a preselected program while L_1 is held constant (thus, L_2 is varying). The program of change in Δ L is susceptible to variation, viz:

20C(1):ΔL gradually increasing during entire period while package is built from core to maximum size (thus, L_2 becomes progressively shorter).

20C(2):ΔL increasing progressively for a long period (say six to ten times t_1) after which it decreases abruptly to its original value (not zero) and again increases progressively; another way of visualizing this program is that a plot of the values of L_2 will show a sawtooth pattern of period of about $6t_1$ to about $10t_1$ in which one leg of the sawtooth is vertical.

20C(3): ΔL increasing progressively for a long period, then decreasing progressively for a like period; e.g., a plot of L_2 shows a flattened triangular form.

20C(4): ΔL varying randomly, consequently L_2 varies randomly.

20D: Stroke L_1 changing while Δ L is also changing in which mode L_1 could change in a straight line path (as in FIG. 20B1) or a curved path (as in FIG. 20B2) while Δ L could change as in 20C1 or 20C2 or 20C3 or 20C4.

FIG. 20E shows a specific mode combining the changing ΔL of FIG. 20C, in this case decreasing progressively (as Δ La, Δ Lb, Δ Lc,) to provide three shortened stroke lengths with no time pause between the completion of the second stroke and the beginning of the third. Total time for the repeating phase is designated as t_t.

From the foregoing and with reference to FIGS. 19 and 24, it will be recognized that the configuration of the yarn in the package of the present invention is unique and novel. In substantially any package of the prior art, if one excludes the reversals, the path of the yarn will generally be seen to be helical. If a departure from a helical path is present, the rate of change in the slope of the helix, in a single traverse cycle, will be almost imperceptibly small. In contrast, the yarn in the package of the present invention, again exclusive of or inwardly of the reversal regions, exhi-bits abrupt, severe and easily perceived inflections or changes in the lay of the yarn at least twice in each of a preponderance of the coils, a coil being defined as the yarn laid down in one traverse cycle.

Referring to a three piece type cam, it should be realized that because parts of a cam are in motion axially, relative to other parts of the same cam, that there will be times at which the separate cam grooves will be perfectly aligned by which is meant that the common helices (e.g., the 30° part) of the separate cam portions are aligned along a common tangent. At the instant of alignment, the cam follower will experience substantially no acceleration and will behave as if being traversed by a prior art cam of unvarying helix angle; thus, for a short period the yarn being wound will be laid down in an unvarying helix. For purposes of definition, in a typical cam, perfect "alignment" will be taken to be within plus or minus about 0.03 inch measured axially. Since the total movement of the cam end portion of a typical cam is about 0.5 inch, then the above-defined "alignment" will occur in about [2(0.03)100/0.5] = 12% of the distance traveled by the cam end portion when it is moving " in" and another 12 percent when it is moving "out" or, since the cam end portions are moved at essentially constant axial velocity, this means that the condition of "alignment" occurs in about 12 percent of the time period t_2. But time period t_2 only amounts to half or less than half of the cycle time t_1; therefore, the time period in which alignment can occur is equal to or less than $\frac{1}{2} \times 12\% = 6\%$ of t_1 which means that helically-laid yarn in an uninterrupted path will appear in 6 percent or fewer than 6 percent of the layers of yarn in the package. Conversely, yarn exhibiting perceptible perturbations or inflections will appear in 94 percent, or more, of the layers of yarn. This effect may be seen by examining the layers of yarn of a package which is accomplished most readily by depositing the yarn on a planar surface by rolling the package. In substantially any package of the prior art, the yarn will appear to lie along straight line paths (except in the reversals). However, for a three piece cam in the package of the present invention, the yarn lines exhibit two inflections in the helical portion of the windings; i.e., as shown in FIG. 19, the yarn will lie along two distinct and separate, generally parallel lines 71 and 72 and extend between them in a reversed curve portion 73. Two such reversed curve portions are shown in FIG. 19. Regardless of the number, each inflection 73 always occurs in less than half the length of a traverse cycle measured circumferentially of the package and usually the inflections 73 do not intrude into the yarn reversals which are of substantially constant shape throughout the package. A smaller helix angle appears at the reversal point of the inflection 73 indicating that the end portion of the cam was "in" or closed upon the central portion. Conversely, a larger angle will appear at the reversal point of an inflection on a yarn line laid down when the cam end portions are in the "open" position. With reference to FIG. 24, inflections 89 in the helical portions of the package windings of a representative package 2 are formed when the cam is in the short stroke (closed cam) position which places the reversals 90 inboard of the package ends 92.

Referring to FIGS. 20B1, 20B2 and 20D, it will be understood, that during part of the winding of a particular package, the stroke L_1 may be reduced to the extent that the purely helical portions of the cam segments will not return to a condition of alignment during the winding of that package; this, of course, means that yarn inflections will occur in all traverse cycles after this condition is reached except that now the inflections will all exhibit smaller helix angles at their reversal points; in a package wound, in part, under these conditions the number of cycles showing inflections will be greater than 88% for the package taken as a whole. These inflections not only serve to change the rate of yarn deposition on the package but also it is noted that the need for ribbon breaking cycles is reduced when winding according to this invention.

Polymer was prepared substantially as described in Example 1 of U.S. Pat. No. 3,416,302 and a mixed shrinkage polyamide yarn was spun. The yarn, having a normal denier after drawing of 30, and 18 filaments, was wound according to the present invention using three-piece segmented cams. Packages containing 3.8 lbs. of yarn were wound at 2600 yds./min. The winding mode was as shown in FIG. 20E with ΔL_a equal to 11/32 inches, ΔL_b equal to 7/64 inches, ΔL_c equal to 1/16 inches, and t_t equal to 4.8 seconds. Operation was at full stroke L_1 for 71 percent of the time cycle t_t. Traverse stroke L_1 was 7-⅛ inches and, for example, traverse stroke L_{2a} was thus 6 7/16 inches. Packages of the same yarn, denier, and filament count were wound using the same process conditions except that conventional traverse cams of fixed profile were employed in place of the segmented cams. The maximum weight of yarn which could be wound on these packages was about 1 ½ lbs., at which weight sloughing of the yarn caused winding breaks. It should be understood that polyamide yarn of this type is difficult to wind into packages of good formation and stability because of its frictional characteristics which result from the inclusion of kaolinite in the polymer and from its high filament modulus. Larger yarn packages provide, of course, an economic advantage to both the yarn producer and user. The appearance of packages made using the segmented cams was much more pleasing aesthetically than that of the control packages. Some of the controls showed overthrown ends which are undesirable. Despite their much greater size, packages wound according to the invention had no overthrown ends, bulge was minimized, and spiral fan defects were much less objectionable than were the same type of defects in the control packages.

The reliefs depicted at lines 49 and 50 in FIGS. 5, 6, 7, 8 were described above as being helical; however, substantially any curve commonly used on cams could be employed, such as a harmonic or a cycloidal curve. Such curves would, of course, have to be generally tangential with adjacent portions of the cam and would be blended or faired together, the general objective being to avoid abrupt accelerations of the cam follower. While the description has been concerned primarily with cams that require two revolutions per traverse cycle, the invention is equally applicable to cams of one revolution per cycle or three or more revolutions per cycle. It should also be realized that the cams as described are suited for one sense of rotation only (arrow 44, FIGS. 5, 7) and cannot be operated in the opposite sense.

Another embodiment shown in FIG. 21 comprehends a two-piece segmented cam. This embodiment comprises a barrel cam cut in half length-wise on parting lines which are in a plane which includes the axis of rotation of the cam; the cam groove 85 has tapered throats 87 on the downstream side of each parting line as seen best in the developed view of FIGS. 22 and 23. It is of interest to note that the maximum width of the tapered throat 87, measured axially at the parting line, is twice the width of the throat of other embodiments (e.g., the three-piece cam). This means that the tapering relief must be longer in a circumferential direction.

The cam-halves 75, 75a (shown in FIG. 21) each have a single integral ring 76b, 76a respectively, which are slidably mounted on a shaft 77; the ring 76a of the cam-half is spaced to permit each cam-half to move axially relative to its neighbor. Stub shafts 78 which extend radially from the shaft 77, being secured thereto, carry gears 79 which engage racks 80 in the respective halves of the cam. On the cam-half 75 shown in FIG. 21, the righthand ring 76b extends well outside the cam and carries a thrust bearing 81 which is arranged to be acted upon by a fixed air cylinder (not shown) which serves to move the cam half back and forth.

In the same recess that carries the racks 80 are rail surfaces 82 which are engaged by bearings 83 mounted on the stub shafts 78 beneath the gears 79. This mechanism serves to transmit driving torque to the cam halves and relieves the rack and gear mechanism of any circumferentially directed loads. A coil spring (not shown) mounted concentrically on the shaft 77 serves to urge the rings 76a, 76b and the two cam-halves axially apart.

In operation, the cam halves are actuated by means similar to those employed with the three-piece embodiments to provide the desired program. It will be realized that packages wound with the two-piece segmented cam will show inflections exactly twice in each of a preponderance of the traverse cycles.

Although the illustrated embodiments disclose particular arrangements for moving the cam ends in concert, it would also be obvious to employ other arrangements. For example, separate annular piston 21 - cylinder 20 assemblies might be used to drive respective cam ends 13 and 14. However the time-based program of events in the winding of a particular package should be essentially identical for each cam end.

What is claimed is:

1. A yarn package comprising a plurality of layers of helical coils, each coil having helical and reversal curve portions, said coils being formed by traversing yarn through successive stroke lengths to form the package and wherein a traverse cycle consists of two successive stroke lengths, there being at least two inflections in the helical portions in each of a preponderance of the traverse cycles throughout the package.

2. The package of claim 1, said stroke lengths being repeatedly decreased to a first value then increased to a second value.

3. The package of claim 2, said first and second values being constant throughout the package.

4. The package of claim 2, said second value being constant, said first value varying throughout the package.

5. The package of claim 4, said second value varying regularly throughout the package.

6. The package of claim 4, said first value varying randomly throughout the package.

7. The package of claim 4, said first value varying regularly throughout the package.

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