United States Patent

Stump et al.

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[45] **May 30, 1972**

[54] METHOD AND APPARATUS FOR CONVOLUTELY WINDING TUBES OF IRREGULAR SHAPES

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[52] **U.S. Cl.**.....**93/81 R**, 93/36 MM, 93/36.3, 93/59 PL, 93/94 R, 93/94 PS, 156/189, 156/446

[51] **Int. Cl.**.....**B31c 1/08**, B31b 1/62, B31b 1/64

[58] **Field of Search**.....93/36.3, 36 MM, 81, 81 MT, 93/94 R, 94 PS, 59 PL; 156/189, 446

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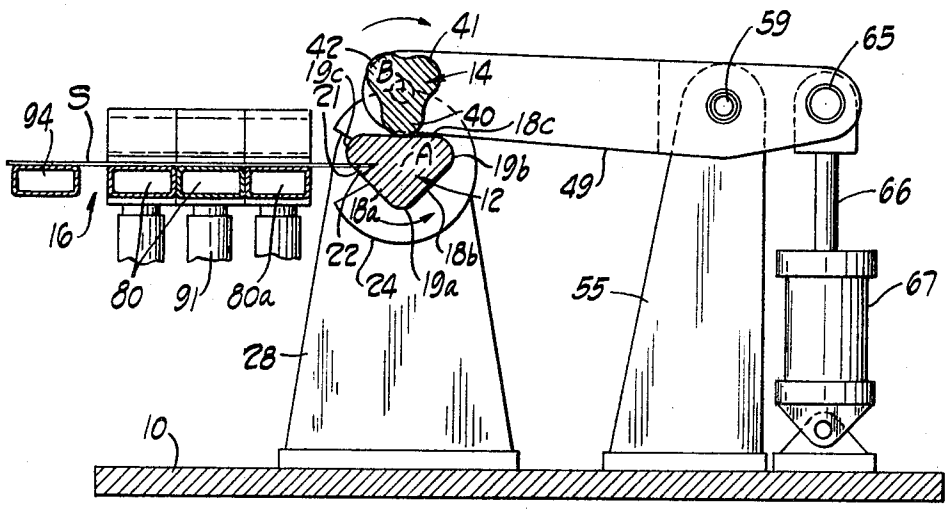
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[57] **ABSTRACT**

Multi-ply tubular members of non-circular cross-sectional shape are convolutely wound of sheet material on a mandrel of the desired non-circular shape. High bond strength is obtained by continuously pressing the sheet against the mandrel and wound plies during winding. For this purpose a presser roll of non-circular cross-sectional shape is biased against the mandrel and wound plies and rotated in timed relationship with the mandrel. The presser roll is shaped so that the combined distance from the axis of the presser roll to its surface and from the axis of the mandrel to its surface, in a plane passing through the axis of each, remains constant during winding.

8 Claims, 8 Drawing Figures



Patented May 30, 1972 3,665,818

3 Sheets-Sheet 1

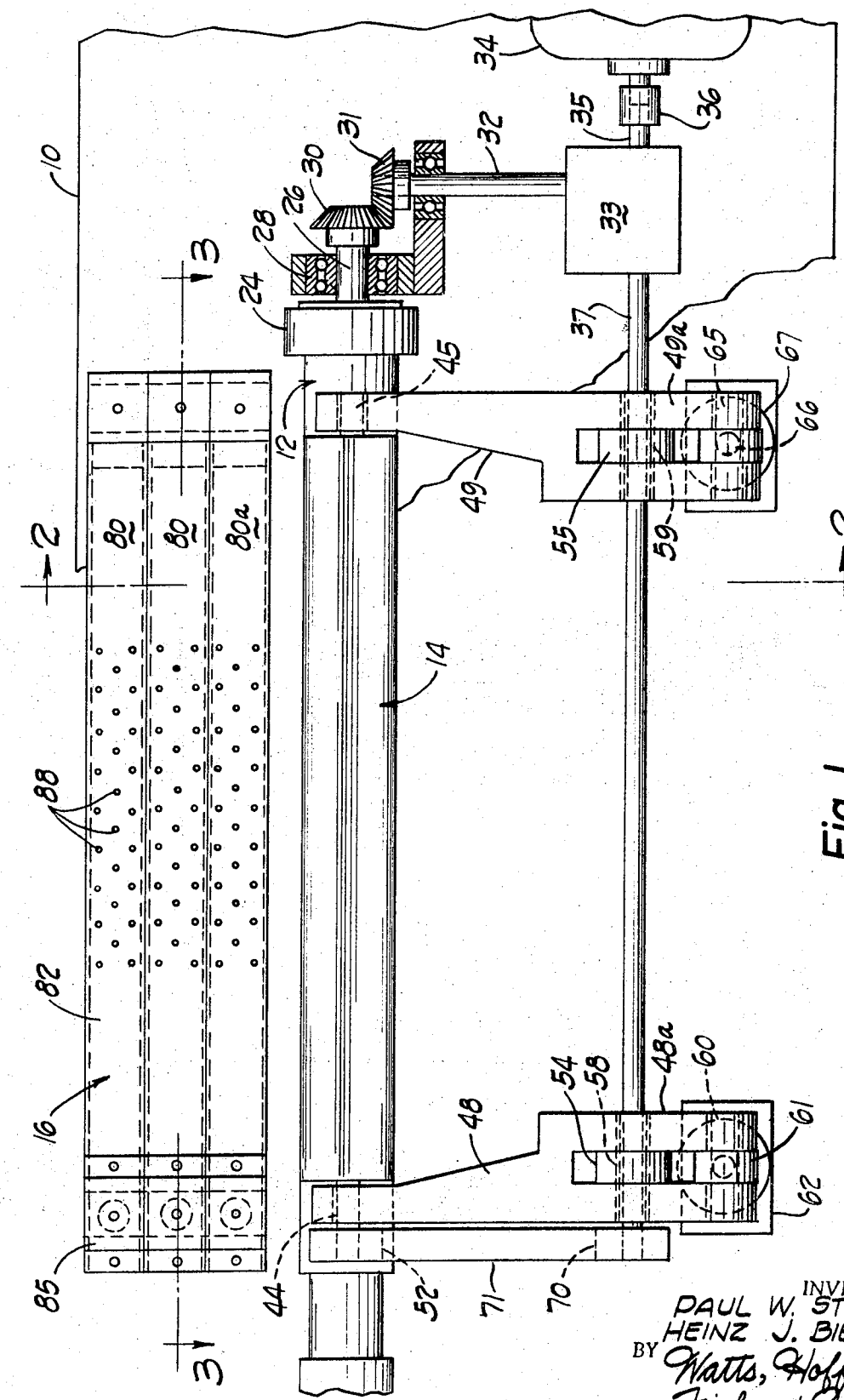


Fig. 1

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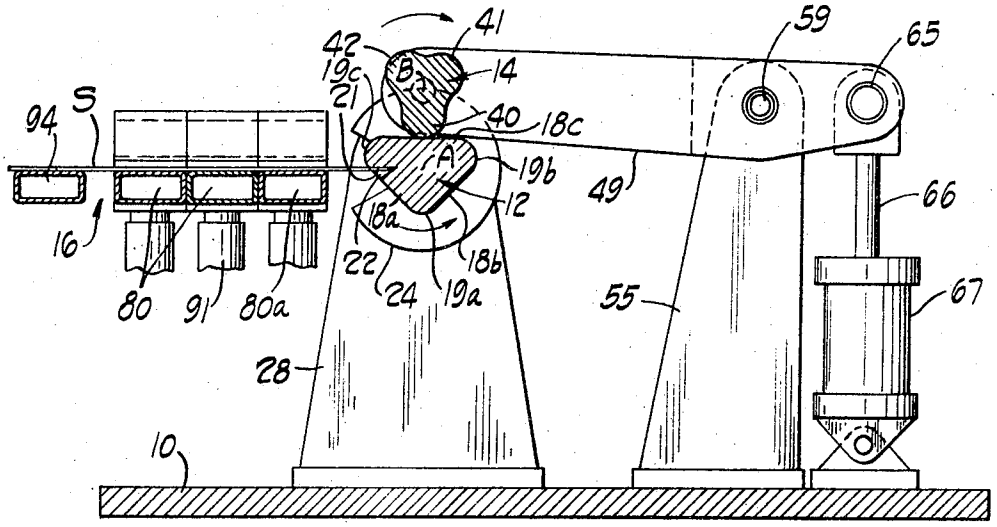


Fig. 2

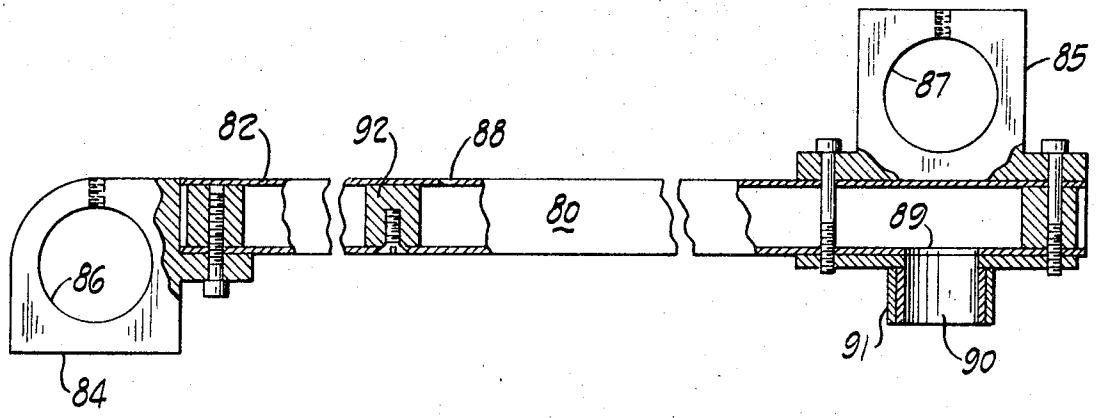


Fig. 3

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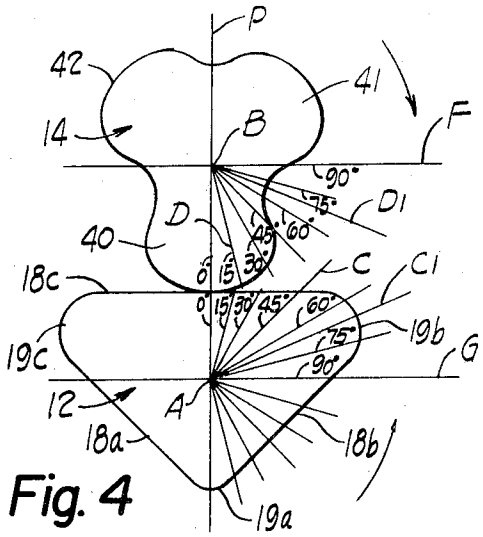


Fig. 4

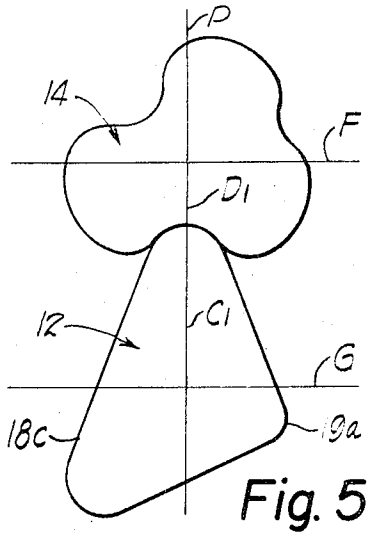


Fig. 5

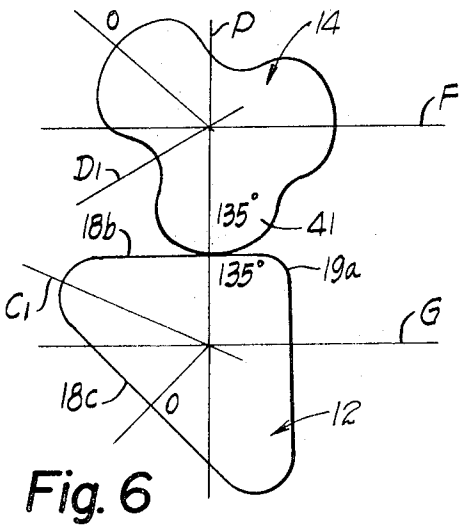


Fig. 6

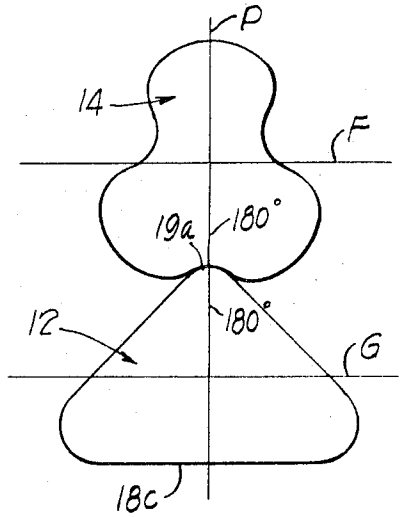


Fig. 7

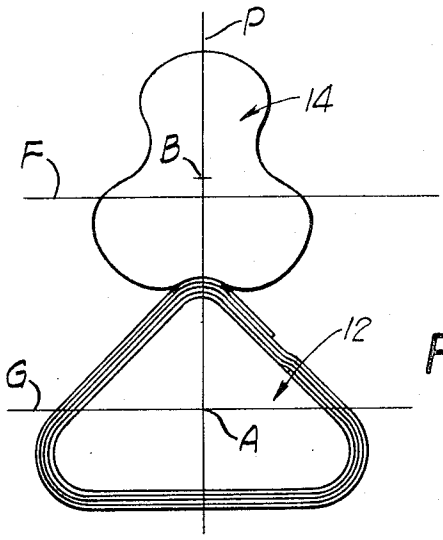


Fig. 8

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METHOD AND APPARATUS FOR CONVOLUTELY WINDING TUBES OF IRREGULAR SHAPES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to convolute winding of tubes non-circular in cross-sectional shape.

2. Description of the Prior Art

In the convolute winding of tubes from sheet material it is conventional to press the sheet against the mandrel and previously wound convolutions during winding. Typically, this is accomplished with a follower roll. Where the mandrel is not cylindrical, the follower roll must reciprocate toward and away from the axis of the mandrel during winding to follow the irregular contour of the mandrel and tube. This may be accomplished by merely biasing the follower roll toward the mandrel or by utilizing a cam operated linkage synchronized with the mandrel rotation. While these methods may operate satisfactory at low production rates on non-round sections, the radial inertia forces developed on the follower roll at high winding speeds and high production rates become a limiting factor in obtaining satisfactory roll pressure. This is especially true on shapes very non-circular, such as triangular cross-sectional shapes. Where insufficient pressure is exerted against the convolutions during winding, the resulting laminations are not suitably adhered or bonded, and the tube will have low bond strength and a shape that departs from that desired.

SUMMARY OF THE INVENTION

The present invention overcomes the drawbacks suffered when known winding techniques are used in high speed winding operations with irregular shapes. In accordance with this invention a rotatable presser roll is used, of a shape that exerts continuous pressure on the mandrel or windings, but which eliminates the need for the roll to reciprocate toward and away from the mandrel during rotation. To this end, the presser roll is shaped so that when it is driven in an opposite direction from the mandrel in a predetermined timed relationship from a predetermined initial relationship, the combined distances from the center of rotation of each to the line of contact remains constant. In the preferred embodiment the mandrel and presser roll are each rotated through 360° cycles of equal time duration and, more particularly, are rotated at equal angular velocities. As a result of the present presser roll construction and operation, the creation of inertia forces of the type previously encountered in the presser roll is avoided and a constant, substantially uniform, pressure is maintained against the convolutions of the sheet. This substantially enhances the interply bonding and ability of the wound sheet to retain the wound shape.

Accordingly, it is a principal object of this invention to provide an improved method and apparatus for convolutely winding tubes of non-circular cross-sectional shape, which permit high production rates and provide improved interply bonding and shape retention. It is a more particular object of this invention to provide an improved winding apparatus utilizing a rotating presser roll having a shape that permits the roll to maintain continuous contact with a tube being wound on a rotating mandrel, without oscillating relative to the mandrel. Other objects, features and advantages of this invention will become apparent from the detailed description that follows, when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a top plan view of winding apparatus embodying the present invention;

FIG. 2 is a transverse sectional view taken along the line 2—2 in FIG. 1;

FIG. 3 is a sectional view taken along the line 3—3 in FIG. 1;

FIGS. 4 to 7 are diagrams showing a triangular mandrel and a presser roll in four different stages of relative rotation, illustrating the manner in which the parts cooperate; and

FIG. 8 is a diagram similar to FIG. 7, illustrating a change in spacing between the mandrel and presser roll after the winding of a sheet.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Apparatus embodying present invention, for convolutely winding tubes of non-cylindrical cross sectional shape from a sheet of material, such as paper, is shown illustratively in FIGS. 1 to 3. The basic apparatus comprises a supporting framework **10**, a winding mandrel **12**, a presser roll **14** and a vacuum table **16**. The winding mandrel, presser roll and vacuum table are supported by the framework **10**. The winding mandrel **12** is an elongated member, rotatably driven about its longitudinal axis, for convolutely winding a sheet S of paper or the like into a tube that corresponds in shape to the cross sectional shape of the mandrel. The presser roll is an elongated roller supported parallel to and adjacent the winding mandrel, for applying pressure to convolutions of the sheet S, as the sheet is wound. The cross-sectional shape of the roll eliminates the need for it to reciprocate relative to the mandrel during the winding of a sheet. The vacuum table **16** serves as a support for the sheet S prior to winding, and causes the sheet to be tensioned during the winding. Typically, when a sheet is to be wound into a tube, it is cut to length from a roll, a suitable adhesive is applied to one surface of the sheet, one end of the sheet is placed into a slot of the mandrel **12** and securely gripped. The mandrel is then rotated to wind the sheet about the mandrel. The movement of the sheet toward the mandrel during winding is retarded by the ambient pressure on the sheet, due to the pressure differential created by the vacuum table. Each convolution of the sheet is pressed against the mandrel **12** or preceding convolution by the presser **14**, to adhere each convolution to the next and to be certain that the convolutions follow the contour of the mandrel.

In the particular embodiment shown, the winding mandrel **12** is triangular in cross section, with rounded corners. In this preferred embodiment, the cross-sectional shape of the mandrel is a right-isosceles triangle having two sides **18***a*, **18***b* of equal length and a hypotenuse **18***c*. The sides **18***a*, *b*, *c* are joined by rounded corner portions **19***a*, *b*, *c*. A longitudinal slot **21** extends along the length of the mandrel, in the side **18***a*, and inwardly toward the central axis of the mandrel, which is indicated at A. The slot **21** is adapted to receive an end of the sheet S. The mandrel is provided with a clamping jaw **22** that is spring biased to a closed or clamping position and which is automatically closed and opened at the beginning and end of each winding cycle, in a manner conventional to winding mandrels.

The mandrel **12** is supported horizontally at opposite ends for rotation about its longitudinal axis A, with the location of the axis fixed relative to the supporting framework **10**. To facilitate different shaped mandrels and the operation of the clamping jaw **22**, the mandrel is supported at each end by rotating head mechanisms, one head mechanism **24** being shown in FIGS. 1 and 2, supported on a rotatable spindle **26** by a bearing block **28**. The spindle **26** is rotatably driven by a bevel gear **30** from a driving gear **31** on the end of an output shaft **32** from a gear box **33**, all carried by the supporting framework **10**. The drive for the gear box comprises an electric motor **34** secured to the framework and coupled to an input shaft **35** by a coupling **36**. If desired, a clutch coupling can be utilized. A second output shaft **37** from the gear box **33** rotates in the opposite direction from the shaft **32** and drives the presser roll **14**, as will be described subsequently.

In the preferred embodiment, the mandrel **12** is more than double the length of the tube to be wound, affording a mandrel portion along which the tube can be slid axially after winding, for curing. After the tube is moved axially, as by an axially movable finger (not shown) that engages one end of the tube, heated pressure plates (not shown) can be applied against the outside surface of the tube to cure the adhesive

that bonds the convolutions. This occurs while the mandrel is stationary, preferably during the time a new sheet is fed to the mandrel, for winding.

The presser roll **14** is supported horizontally above the mandrel **12**, with its central longitudinal axis B parallel to the axis A of the mandrel. In the embodiment shown, the presser roll has three lobes **40, 41, 42**. The shape of the roll will be described in more detail in connection with FIGS. **4** to **7**. The presser roll **14** is supported at opposite ends for rotation about the axis B by two stud shafts **44, 45**, each of which is journaled in a forwardly extending portion of a pivoted presser arm **48, 49**. The stud shaft **44** extends through the presser arm **48** and supports a toothed pulley wheel **52** on its distal end. The pulley wheel **52**, shaft **44** and presser roll **14** are in fixed relationship so that rotation of the pulley wheel drives the presser roll about the axis B. Each presser arm **48, 49** has a bifurcated end **48*a*, 49*a***, respectively, that straddles a support pedestal **54, 55**, respectively, and each is supported on a hollow pivot shaft **58, 59** that projects from opposite sides of the respective pedestal **54, 55**. The pedestals, in turn, are secured to the support frame **10**. A pin **60** extends through the bifurcated end **48*a*** of the presser arm **48** and pivotally connects the presser arm to the end of a vertically disposed piston rod **61**. The piston rod **61** extends upward from a double-acting fluid-actuated cylinder **62**, pivotally supported at its lower end to the supporting frame **10**. Similarly, a pin **65** in the bifurcated end **49*a*** of the presser arm **49** connects the arm to the end of a piston rod **66** from a double-acting fluid cylinder **67** secured to the supporting frame **10**. The fluid cylinders **62** and **67** can be operated to withdraw the piston rods and thereby pivot the presser arms and lift the presser roll **14** from the mandrel **12**, for example, during the removal of a wound tube. During a winding operation fluid pressure is applied to extend the piston rods to yieldably bias the presser roll **14** against the mandrel **12** and the convolutions formed from the sheet being wound.

The presser roll **14** is driven from the drive shaft **37**, which extends through the hollow pivot shafts **58, 59** in the pedestals **54, 55**. To this end the drive shaft **37** extends beyond the presser arm **48** and carries a toothed pulley wheel **70** fixed against relative rotation. A timing belt **71** connects the pulley wheel **70** with the pulley wheel **52**, so that the arms **48, 49** can pivot and rotation of the drive shaft **37** will drive the presser roll **14**. The pulley wheels **70** and **52** are of equal size, as are the gears **30, 31**. Thus, when the shafts **32** and **37** are driven at equal speeds, the presser roll **14** is driven at an equal angular velocity (i.e., rotational speed) to the winding mandrel **12**, but in an opposite direction.

A specific shape of a winding mandrel **12** and a presser roll **14** for winding a right-isosceles triangular-shaped tube is shown in detail in FIGS. **4** to **8** of the drawings, which also illustrate the manner in which the presser roll coacts with the mandrel to maintain surface contact during winding of a sheet about the mandrel, through 180° of rotation. FIGS. **4** to **7** show four progressive positions, beginning at a point of contact between the mandrel and presser roll at the center of the hypotenuse **18*c*** of the mandrel, and ending at the right angle apex **19*a***, opposite the hypotenuse. For illustrative purposes, positions of angular rotation of the mandrel through the 180° shown, are indicated in 15° increments by imaginary lines C radiating from the axis A. It will be readily apparent from the drawings that the distance from the axis A to the surface of the mandrel along the different imaginary lines C varies, so that in any fixed plane, such as the imaginary plane P, that passes through or contains the axis A of the mandrel and the axis B of the presser roll, the actual radial distance of the mandrel surface from the axis will continually change during rotation of the mandrel. The radial distance is shortest along the line indicated 0 (zero degrees), which bisects the hypotenuse surface **18*c*** and is longest at the line C1 that bisects the corner **19*d***.

The shape of the presser roll **14** is shown in a similar manner in FIGS. **4** to **8**, and the surface profile varies in distance from the axis B, inversely from that of the mandrel, with angular displacement (indicated by lines D) in an opposite direction from that of the mandrel when in the relationship depicted. Thus, that portion of the presser roll surface farthest from the axis B lies along the 0° line and that portion closest to the axis B lies along the line D1, which is angularly displaced from the 0° line a distance equal to the angular displacement of the line C1 from the 0° line of the mandrel. As will be appreciated from the different degrees of rotation shown in FIGS. **4** to **7**, in which the positions of the axes A and B have not changed, the sum of the distance from the axis A to the surface of the mandrel **12** and the distance from the axis B to the surface of the presser roll **14** along the radial lines of equal angular displacement, is constant. As a result, when the mandrel **12** and roll **14** are rotated about their respective axes at equal angular velocities in opposite rotational directions, the surfaces can be maintained in contact without relative movement of the axes. It will also be appreciated from FIGS. **4** to **7** that the surface or peripheral distance on the mandrel or presser roll for a given angular distance may be different. Thus, where the surface of the presser roll is spaced a substantially greater distance from the axis B than is the corresponding surface of the mandrel from the axis A, as at the 0° lines shown in FIG. **4**, the surface distance to the line of 15° rotation on the mandrel is substantially shorter than the surface distance to the line of 15° rotation on the presser roll. These lines will nevertheless meet in the plane P upon 15° of rotation of the mandrel and roll because of a proportionately higher surface velocity of those surface portions farthest from the respective axis.

FIG. **5** illustrates the mandrel and presser roll after sufficient rotation from the position shown in FIG. **4** to place the imaginary line C1, bisecting the angle **19*b***, in the plane P. At this position, the line D1 of the presser roll is also in the plane P and, as illustrated, the sum of the distances from the axis A to the surface of the mandrel **12** along the line C1 and the distance from the axis B along the line D1 to the surface of the presser roll is equal to the distance between the axes A and B in FIG. **4**. This is illustrated by the imaginary, equi-distant, parallel lines F and G that pass through the axes A and B in FIGS. **4** to **7**.

FIG. **6** illustrates the mandrel and presser rolls after 135° of rotation, at which position the point along the side **18*b*** closest to the axis A is in the plane P and is contacted by that surface portion of the lobe **41** having the greatest radial distance from the axis B.

FIG. **7** illustrates the winding mandrel and presser roll after 180° of rotation from the position shown in FIG. **3**, at which point the apex **19*a*** of the mandrel is in contact with the presser roll. It will be apparent that the next 180° of rotation of the mandrel and presser roll will be the same as that shown in FIG. **4** to **7**, if considered in an opposite direction, i.e., from the apex **19*a*** to the center of the hypotenuse **18*c***.

The actual distance between the axes A and B, as shown in FIGS. **4** to **7**, is constant only until a sheet is wound about the mandrel **12**. As a sheet is wound, the thickness of the sheet and each successive convolution requires a somewhat greater spacing between the axes. This is illustrated in FIG. **8**, which shows the axis B raised above the imaginary line F, by the thickness of the convolutions about the mandrel **12**. The displacement of the presser roll is accommodated by the presser arms **48, 49** and the yieldable biasing force created by the fluid cylinders **62, 67**.

Referring now to FIGS. **1** to **3**, it will be seen that the sheet S to be wound is supported during winding by the vacuum table **16**, in the plane of the slot **21** of the mandrel, when the mandrel is oriented as shown in FIG. **2**. The vacuum table is comprised of a plurality of vacuum boxes **80**, an end box **80*a*** being located closely adjacent the winding mandrel **12**. All of the vacuum boxes have a flat, upper, surface **82** in a common plane. The boxes are directly adjacent one another, side-by-side, are generally rectangular in shape, and extend substantially the length of the mandrel to provide a support for the sheet being wound. Opposite ends of the boxes are secured to

a common support **84** at one end and **85** at the other end. Each support has a tubular aperture **86, 87**, respectively and is received on a horizontal mounting rod (not shown). In general, it is not necessary that the entire support length of the vacuum boxes be constructed to create a pressure differential between the upper and lower surfaces of the sheet being supported, and for that reason only a limited area of each box is provided with apertures **88** in the flat upper surface **82**. The end of each box supported by the support **85** communicates through an opening **89** in the lower surface, to a coupling **90** and an exhaust conduit **91**. The boxes are preferably obstructed at the opposite side of the apertured portion from the openings **89**, by blocks **92**. An additional vacuum box **94** is provided, that is movable in a direction parallel to the mandrel, and is used to transport a sheet of paper to be wound from a receiving position adjacent the end **84** of the vacuum boxes, onto the vacuum boxes, and at the same time sliding one edge of the sheet along the slot **21** of the mandrel, so that the sheet is engaged in the winding mandrel when positioned. The movable vacuum box is separately connected with a flexible conduit to the source of reduced pressure. When a vacuum is applied to the table through the conduits **91**, the reduced pressure beneath a portion of the sheet supported on the vacuum boxes retards movement of the sheet, which must slide across the boxes during winding, and thereby places the sheet in tension as it is wound.

To summarize the operation of the apparatus, a sheet S to be wound into a tube of non-circular cross-sectional shape is fed along the support frame **10** in a direction parallel to the mandrel **12**, onto the vacuum table **16**. As the sheet is moved onto the table, an adhesive is applied to the upper surface of the sheet and the leading end slides into the longitudinal slot **21** of the mandrel and is gripped by the clamping jaw **22**. A vacuum is applied to the table **16** to resist movement of the sheet relative to the table during winding and fluid pressure is applied to the cylinders **62, 67** to bias the presser roll **14** against the mandrel **12**. The mandrel and presser roll are then driven at equal angular velocity in opposite directions by the electric motor **34** and associated drive mechanism. During rotation, the presser roll **14** continuously presses against the convolutions of the sheet that are wound about the mandrel. This pressure is applied progressively over the entire surface, without oscillation of the presser roll axis. As the sheet S is progressively wound about the mandrel, the axis of the presser roll is gradually moved farther away from the axis of the mandrel by the increased thickness of the tube wall being formed. This movement of the presser roll away from the mandrel is yieldably resisted by the fluid pressure of the cylinders **62, 67**. The biasing force of the fluid pressure plus the absence of oscillation of the presser roll assures that the pressure exerted by the presser roll upon the sheet being wound is continuous. When the sheet has been completely wound about the mandrel **12**, rotation of the mandrel and presser roll is stopped by either deenergizing the motor **34** or declutching the drive. Fluid to the cylinders **62, 67** is reversed and the presser roll is raised from the mandrel and wound tube. The clamping grip on the leading end of the sheet engaged by the mandrel is released and a finger is moved along the mandrel, sliding the wound tube either off the mandrel or to an axially displaced portion of the mandrel for curing, and returns. Another sheet is then moved onto the table **16**, gripped by the mandrel, and the cycle is repeated.

As will be evident from the described embodiment of this invention, an improved winding mechanism has been provided in which a tube of non-circular cross sectional shape can be convolutely wound at high speeds while substantially uniform continuous pressure is applied against the convolutions to improve interply bonding and shape retention and thereby provide an improved product capable of being manufactured at high production rates.

While a preferred embodiment of this invention has been described in detail, it will be understood that various modifications or alterations may be made therein, without departing from the spirit and scope of the invention set forth in the appended claims.

We claim:

1. In apparatus for convolutely winding a sheet into a tube having a non-circular cross-sectional shape: an elongated mandrel having a non-circular shape in cross section; means supporting said mandrel for rotation about its central longitudinal axis; means to rotate said mandrel about said axis; an elongated presser roll having a non-circular shape in cross section different from that of said mandrel; means supporting said presser roll for rotation about its longitudinal axis and with its longitudinal axis parallel to and adjacent the axis of said mandrel; the shapes of said mandrel and presser roll being such that the combined distance from the central longitudinal axis to the surface of each, in the plane of the two axes, remains constant when both the mandrel and the presser roll are rotated in opposite directions and in a predetermined timed relationship from a predetermined initial relationship; and means to rotate said presser roll in said predetermined timed relationship with said mandrel.

2. In apparatus for convolutely winding a sheet into a tube having a non-circular cross-sectional shape: an elongated mandrel having a non-circular shape in cross section; means supporting said mandrel for rotation about its central longitudinal axis; means to rotate said mandrel about said axis; an elongated presser roll having a non-circular shape in cross section different from that of said mandrel; means supporting said presser roll for rotation about its longitudinal axis and with its longitudinal axis parallel to and adjacent the axis of said mandrel; the shapes of said mandrel and presser roll being such that the combined distance from the central longitudinal axis to the surface of each, in the plane of the two axes, remains constant during equal angular rotation in opposite directions from a predetermined starting relationship; and means to rotate said presser roll at an angular velocity equal to that of said mandrel.

3. In apparatus for convolutely winding a sheet into a tube having a non-circular cross-sectional shape: an elongated mandrel having a non-circular shape in cross section; means supporting said mandrel for rotation about its central longitudinal axis; means to rotate said mandrel about said axis; an elongated presser roll having a non-circular shape in cross section different from that of said mandrel; means supporting said presser roll for rotation about its longitudinal axis and with its longitudinal axis parallel to and adjacent the axis of said mandrel; the shapes of said mandrel and presser roll being such that the combined distance from the central longitudinal axis to the surface of each, in the plane of the two axes, remains constant during rotation of each in opposite directions in timed relationship through 360° cycles of equal time duration; and means to rotate said presser in timed relationship with said mandrel.

4. Apparatus as set forth in claim **3** wherein said means supporting said presser roll permits changes in the distance between the axes of the follower and mandrel and includes means yieldably biasing said presser roll toward said mandrel.

5. Apparatus as set forth in claim **4** wherein said mandrel is right-triangular-shaped in cross section with rounded corners and said presser roll has a cross-sectional shape having three lobes.

6. In apparatus for convolutely winding a sheet into a tube having a non-circular cross-sectional shape: an elongated mandrel having a non-circular cross-sectional shape and means for securing an end of a sheet to the mandrel; means for supporting said mandrel for rotation about its central longitudinal axis; means to rotate said mandrel about said axis; an elongated presser roll having a non-circular shape in cross section; means supporting said presser roll for rotation about its longitudinal axis and with its longitudinal axis parallel to and opposite the axis of said mandrel; at least one of said means for supporting said mandrel and said means supporting said presser roll being constructed to permit a change in transverse distance between the axes thereof; means for yieldably biasing

said mandrel and presser relatively toward one another; the shapes of said mandrel and presser being such that the combined distance from the axis to the surface of each in the plane of the two axes remains constant during rotation of each in opposite directions in timed relationship; and means to rotate said presser in said timed relationship with said mandrel.

7. In a method of convolutely winding a tube of non-circular cross-sectional shape from a sheet of paper or the like, the steps comprising: securing an end of a sheet to an elongated mandrel of non-circular cross-sectional shape; rotating said mandrel about a fixed longitudinal axis to wind the sheet about the mandrel; rotating an elongated presser roll in an opposite direction from said mandrel and in timed relation therewith about a longitudinal axis parallel to the axis of said mandrel, said presser roll being non-circular in cross-sectional shape and having a surface contour that varies in distance from its longitudinal axis in correlation with the shape of the mandrel such that the combined distance from the axis to the surface of each of the mandrel and presser roll in the plane of the two axes remains constant during rotation of the mandrel and presser roll in timed relationship; supporting said presser roll for movement toward and away from said mandrel; yieldably maintaining said presser roll in continuous contact with said sheet during rotation of the mandrel and presser roll without reciprocation of said presser roll axis relative to said mandrel axis; and permitting said presser rolls axis to progressively move laterally away from said mandrel axis as said sheet is wound.

8. The method as set forth in claim 7 including the step of rotating the mandrel and presser roll at equal angular velocities.

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