

Feb. 1, 1966

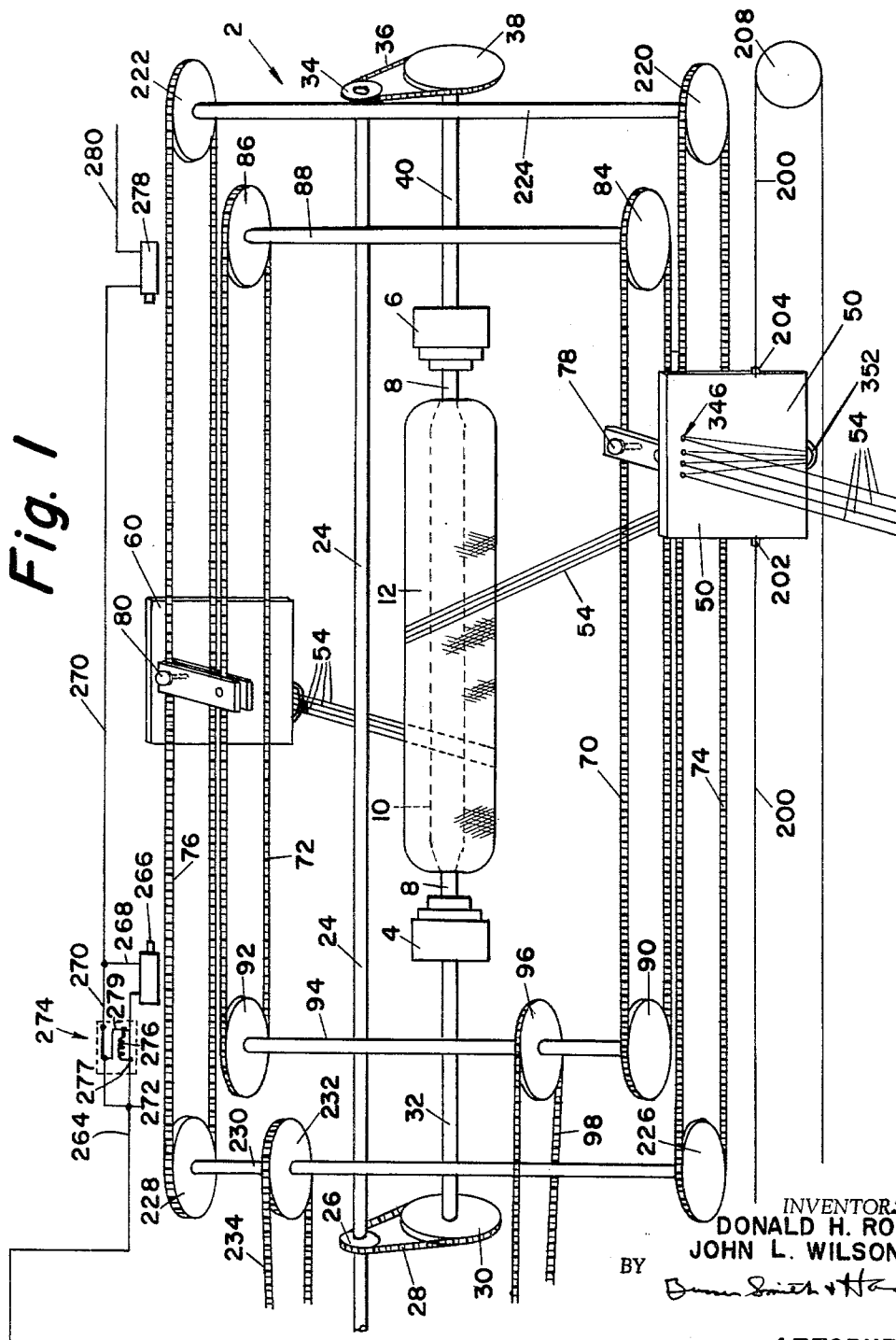
D. H. ROSS ETAL

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FILAMENT WINDING MACHINE

Filed Aug. 15, 1963

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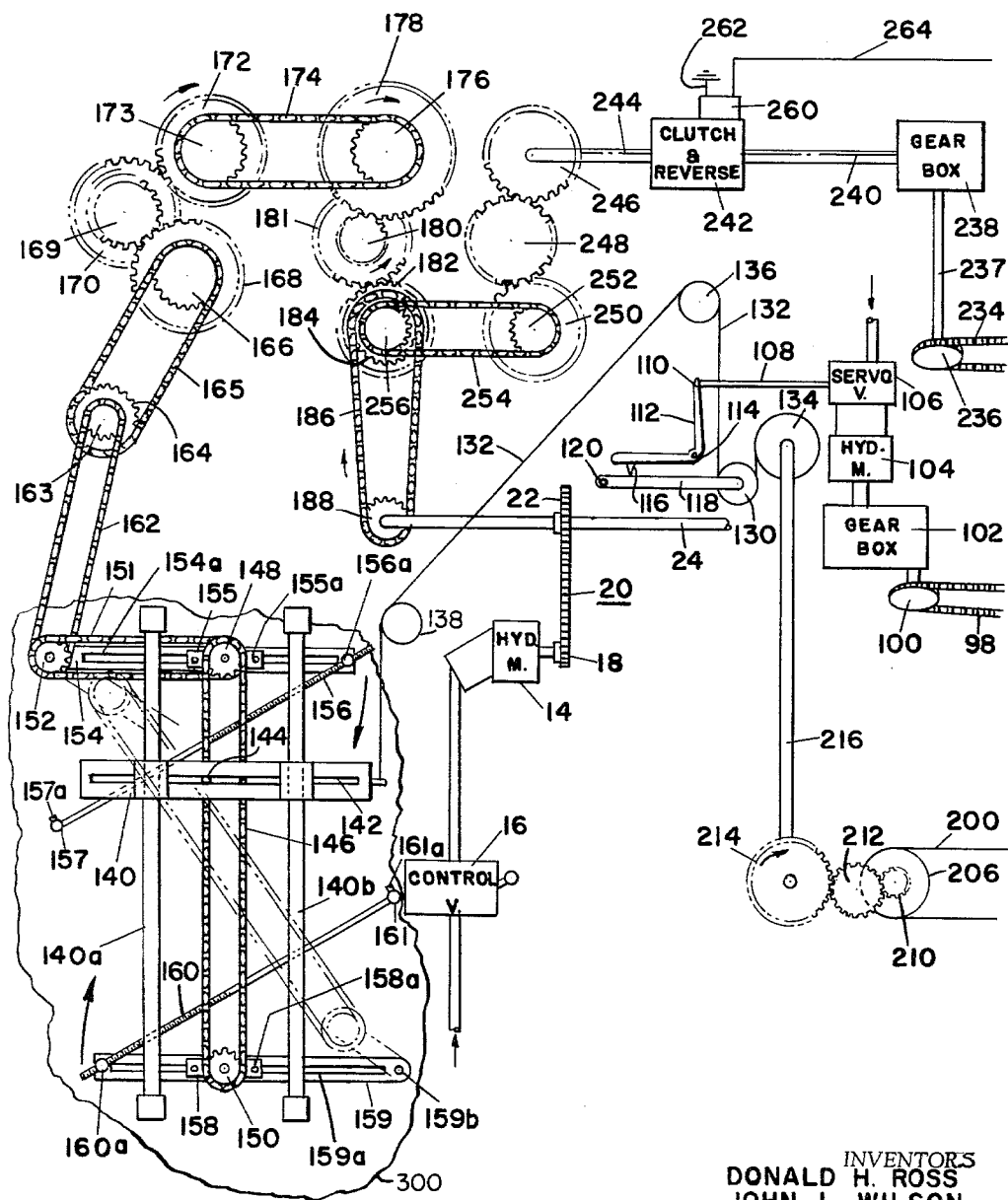
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Filed Aug. 15, 1963

3 Sheets-Sheet 2

Fig. 2



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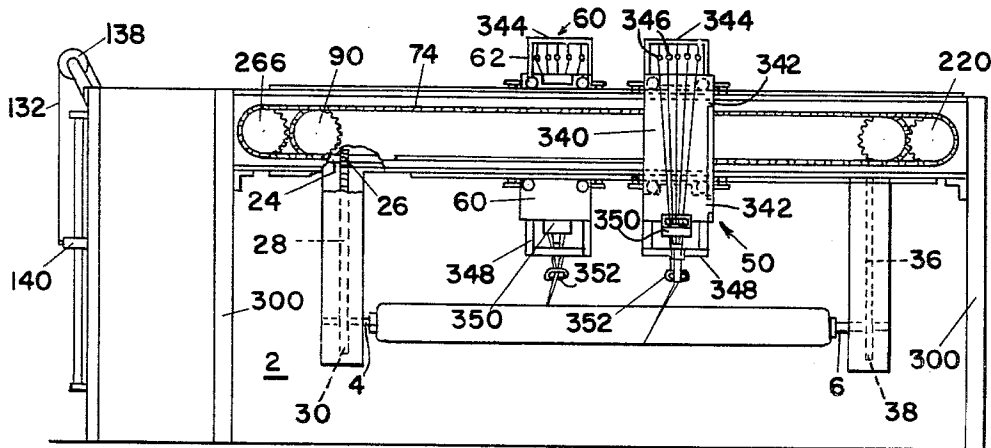


Fig. 3

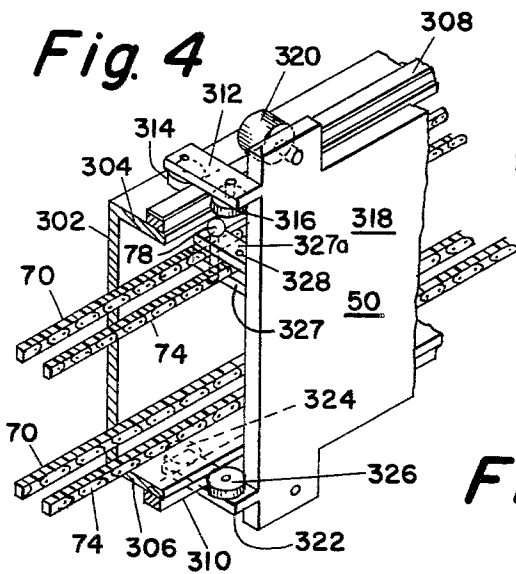


Fig. 4

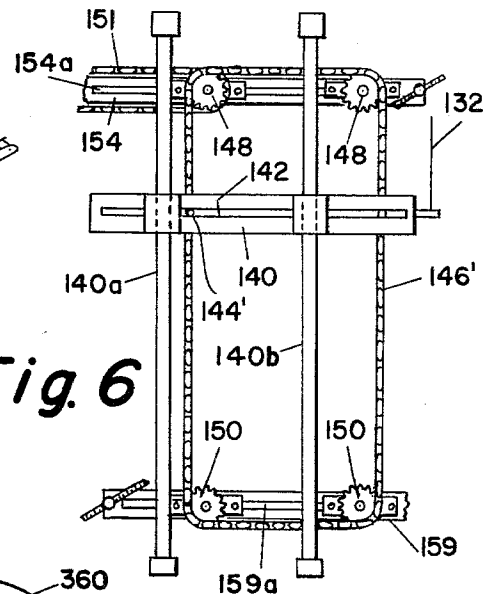


Fig. 6

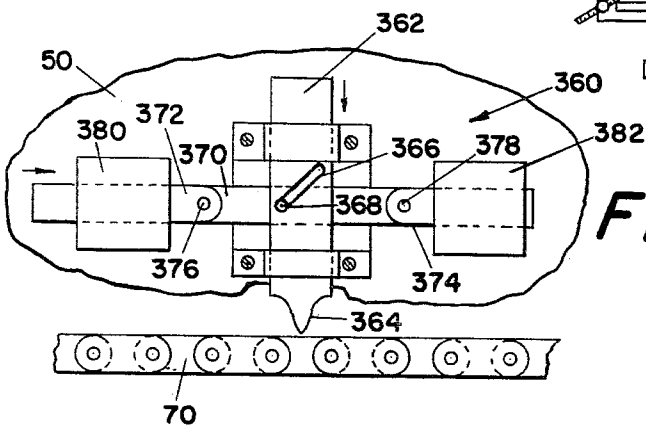


Fig. 5

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FILAMENT WINDING MACHINE

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Filed Aug. 15, 1963, Ser. No. 302,338

5 Claims. (Cl. 242-7)

This invention relates to a filament winding machine which is of particular utility in winding resin coated filament for example, a glass fiber filament, on a mandrel or the like to form a hollow structure for example, a tubular structure.

In general, it is well known to wind filaments on a mandrel together with a resin coating or binder and hence there is no necessity for detailing the general process involved here. Normally the filaments, which are preferably of glass, are fed for winding in the form of a band formed by a substantial number of filaments and the band is helically wound or variously helically and levelly wound.

A level wind pattern is produced when the lead of the carriage for each revolution of the mandrel, is equal to the width of the band. For example, the band of fibers is one-inch wide, therefore, the carriage will advance one-inch for each revolution of the mandrel.

A helix wind pattern is used when the width of the band is too narrow with respect to the mandrel diameter to completely fill in each revolution. It is necessary therefore, to wind on one band the length of the mandrel, then repeat with an additional band until the whole mandrel is covered. Consider a mandrel 3 inches in diameter and a band width of one-inch. To make a 45 degree lay, the lead would be approximately nine-inches, therefore, it requires approximately nine one-inch bands be placed side by side. The fundamental principle of a filament winding machine is to precisely position the band of glass from the carriage relative to the mandrel. The machine must be capable of laying down a band comprising a multiple of fibers such as glass, at a determined angle relative to the shaft. It must also be able to generate a dome at the end of the mandrel such as a pressure bottle and return to a position whereby the second band will lay precisely adjacent to the original band laid down, and so progressing until the entire mandrel is covered.

The machine in accordance with this invention solves many of the problems existing in the art of filament winding machines. At the outset, one of the major problems in the field is preventing the disruption of the filament winding operation due to the dripping of the binder, such as a synthetic resin, onto the various parts of the winding machine. This invention provides a machine wherein any excess binder falls directly to the floor on which the machine is mounted or into a pan supported on the floor, if desired. Thus, the binder in no way fouls the filament winding machine and can be readily cleaned up.

In addition to the obvious advantages provided by the machine winding in an inverted position, an allowance for extremely large diameter mandrels to be wound which are in such a location that they can be readily policed by the operating personnel.

In addition, this invention provides a highly effective control system for carriages employed in the winding operation. As previously explained, the machine must have a highly effective control system so that the carriage relative to the mandrel, will maintain the proper relative positions.

Further, this invention reduces distortions in the articles formed by filament winding by substantially reducing or eliminating entirely torsional distortions of the mandrel by driving the mandrel at both ends thereof.

2

These and other objects of the invention will become apparent from a reading of the following description in conjunction with the drawings in which:

FIGURE 1 is a diagrammatic view of the mandrel and carriage portions of a filament winding machine in accordance with the invention;

FIGURE 2 is a diagrammatic view of the associated control mechanism for use with the filament winding machine of FIGURE 1;

FIGURE 3 is a front elevation of an actual embodiment of a filament winding machine incorporating the elements shown in FIGURES 1 and 2;

FIGURE 4 is a perspective view of details of construction of a carriage in the machine of FIGURE 3;

FIGURE 5 is an elevation of an alternative arrangement for automatically engaging and disengaging a carriage to a chain; and

FIGURE 6 is a diagrammatic view of an alternative computer chain arrangement.

Referring now to FIGURES 1 and 2, there is a diagrammatic showing of a filament winding machine 2 in accordance with the invention. With particular reference to FIGURE 1, machine 2 is provided with a head stock 4 and a tail stock 6, each respectively engaging a rod 8 secured to a mandrel 10 on which a domed tubular object 12 is being formed.

Head stock 4 and tail stock 6 are driven by a hydraulic motor 14 (FIGURE 2) controlled by a controller indicated at 16. Motor 14 drives a sprocket 18 which in turn drives a chain 20 connected to a sprocket 22. Sprocket 22 is connected to a shaft 24 which drives sprocket 26 (FIGURE 1) carrying a chain 28 which drives a sprocket 30. Sprocket 30 is connected to a shaft 32 which is connected to and drives head stock 4. Shaft 24 is also connected to sprocket 34 which drives chain 36 which in turn drives sprocket 38. Sprocket 38 is connected to shaft 40 which in turn is connected to and drives tail stock 6.

A filament carriage 50 mounted for reciprocal movement parallel to the axis of the head and tail stocks carries glass filaments 54. A second filament carriage 60 is mounted for reciprocal movement parallel to the axis of the head and tail stocks and also carries glass filaments 54.

The reciprocation of carriages 50 and 60 for helical winding is accomplished by means of endless chains 70 and 72, respectively, while the reciprocation of these carriages for level winding is accomplished by endless chains 74 and 76, respectively. Carriage 50 is connected to chain 70 or chain 74 by a bolt 78 passing between adjacent chain links. Similarly, carriage 60 is connected to chain 72 or chain 76 by a bolt 80.

Helical winding chains 70 and 72 are engaged by sprockets 84 and 86, respectively, the sprockets being connected by a shaft 88. Chains 70 and 72 are also engaged by sprockets 90 and 92, respectively, the said sprockets being connected by shaft 94 which is driven by a sprocket 96 carrying a chain 98 driven by a sprocket 100 (FIGURE 2). A gear reducer 102 (FIGURE 2) drives sprocket 100 and in turn is driven by a reversible hydraulic motor 104 which is controlled by a servo-valve 106. The position of servo-valve 106 is controlled by a link 108 pivoted at 110 to a bell crank 112 which is pivoted at 114. Bell crank 112 has a dependent finger 116 which engages a lever 118 which is pivoted at one end at 120 and at the other end carries a pulley 130. A wire 132 runs over pulley 130 and is wound up onto drum 134.

The position of lever 118 and hence the position of servo-valve 106 is controlled by an analogue computer device (FIGURE 2) which reproduces on a reduced scale the desired travel of the carriage and is provided with a feed back input from carriage 50. Wire 132 runs

over pulley 136 and pulley 138 and is secured to plate 140 which is slidably mounted on rods 140a and 140b. Plate 140 is provided with a slot 142 which is engaged by a pin 144 secured to an endless chain 146. Chain 146 passes over double sprocket 148 and sprocket 150. Sprocket 148 is driven by a chain 151 carried by a double sprocket 152 which in turn is driven by chain 162.

Double sprocket 152 is mounted for rotation on a swinging arm 154 which has a longitudinal slot 154a and is pivotally mounted on the axis of sprocket 152 on a pivot not shown. Double sprocket 148 is mounted for rotation on clamp 155 which is clamped to arm 154 by bolts 155a passing through slot 154a to permit adjustment of the clamp longitudinally of the arm. The angular position of arm 154 is controlled by threaded rod 156 which passes through a nut 156a secured to arm 154 and is held in pivot 157 by a set screw 157a. Sprocket 150 is mounted for rotation on clamp 158 which is clamped to swinging arm 159 by bolts 158a passing through a longitudinal slot 159a in arm 159 which is pivotally mounted at 159b. The angular position of arm 159 is controlled by a threaded rod 160 which passes through a threaded nut 160a and is secured to pivot 161 by a set screw 161a.

Sprocket 163 carries chain 162 and is connected to sprocket 164 driven by chain 165. Sprocket 166 drives chain 165 and in turn is driven by a gear 168 which is driven by gear 169 which in turn is driven by a gear 170 driven by gear 172. Gears 168, 169, 170 and 172 are employed to provide for the desired lead or lag of the filaments necessary to provide for the laying of the band of filaments adjacent to each other in successive passes in the same direction rather than overlapping.

A sprocket 173 is secured to gear 172 and is driven by a chain 174 carried by a sprocket 176 secured to a gear 178 which is driven by a gear 180. Gears 178 and 180 are selected to provide for the desired ratio between the speed of the chain 70 and the computer so as to permit a relatively small analogue movement of plate 140 to represent the desired travel of the carriage 50.

Gear 180 is secured to gear 181 which is driven by a gear 182 which is connected to sprocket 184 which is driven by chain 186 which is in turn driven by a sprocket 188 secured to shaft 24 which is the mandrel drive shaft. Thus, the analogue computer gets its basic input from the same shaft which drives the head stock and tail stock and which drives chain 70 to move carriage 50.

Feed back from carriage 50 is provided by means of a wire 200 (FIGURE 1), one end of which is connected to carriage 50 at 202 and the other end of which is connected to carriage 50 at 204. Wire 200 has several turns taken around drum 206 (FIGURE 2) and passes around pulley 208 (FIGURE 1). Drum 206 is connected to gear 210 which drives gear 212 which in turn drives gear 214. Gear 214 drives feed back drum 134 through shaft 216 which is connected to gear 214 and drum 134. Gears 210, 212 and 214 are selected to provide for a linear rate of rotation of the surface of feed back drum 134 which is substantially less than the linear speed of carriage 50 and wire 200. More specifically, they are selected to provide for a surface speed of drum 134 which is equal to the linear rate of travel of plate 140 as caused by the movement of pin 144 between sprockets 148 and 150.

The level wind drive chains 74 and 76 (FIGURE 1) are carried by sprockets 220 and 222, respectively, which are connected by a shaft 224 and are also carried by sprockets 226 and 228 connected by a shaft 230. Shaft 230 is driven by sprocket 232 carrying a chain 234 which is driven by a sprocket 236 (FIGURE 2). Sprocket 236 is connected to a shaft 237 which is driven by a reduction gear box 238 which is driven by shaft 240 which in turn is driven by a reversible transmission indicated at 242. A shaft 244 drives transmission 242 and in turn is driven by a gear 246 which is driven by a gear 248 in turn driven by a gear 250. Gear 250 is driven by a sprocket 252

which carries a chain 254 driven by sprocket 256 which is connected to sprocket 184 which, as previously described, is driven from shaft 24 through sprocket 188 and chain 186. The drive from shaft 24 through to chains 74 and 76 determines the desired reduction to accomplish the level winding. Changes in the pitch of the level winding can readily be accomplished by changing the ratios between gears 246, 248 and 250.

Reversing transmission 242 is controlled by a solenoid 260 which is connected to ground by line 262 and is connected to a line 264 which is connected to normally open switch 266 which in turn is connected to a line 268 connected to line 270. Line 270 is connected to line 264 at 272 and contains a relay 274 which is closed by a coil 276 connected to line 264 at 277 and to both lines 270 and 264 by a line 279. Line 270 is connected to a normally closed switch 278 which in turn is connected to a power supply line 280. Switches 266 and 268 are engaged by carriage 60, respectively, at the end of its desired travel in each direction to cause a reversal of its direction of movement.

Referring now to FIGURES 3 and 4, there is shown a side elevation of a machine for filament winding incorporating the parts shown in FIGURES 1 and 2 and where shown in FIGURE 3 bearing the same numerals. The showing of FIGURE 3 includes structural details which are not shown in FIGURES 1 and 2 and which will be described with particular regard to the carriages for which a more detailed disclosure is deemed desirable to fully clarify the invention.

Referring first to FIGURE 3, the machine 2 has a frame 300. Referring now to FIGURE 4, frame 300 is provided with a pair of opposed outer facing longitudinal channel shaped beams only one of which is shown at 302. Beam 302 has an upper flange 304 and a lower flange 306, a guide strip 308 being secured to flange 304 and a guide strip 310 being secured to flange 306. An arm 312 carries rollers 314 and 316 which engage opposite sides of strip 308, the arm being secured to an upstanding plate 318 which comprises a substantial portion of carriage 50. A roller 320 mounted on plate 318 engages the top surface of strip 308. An arm 322 is secured to the lower left-hand side of plate 318 as viewed in FIGURE 4 and carries a pair of rollers 324 and 326 which engage opposite sides of guiding strip 310. This completes the description of the mounting and guiding arrangement for the left-hand side of plate 318 as viewed in FIGURE 4 and the right-hand side of plate 318 is guided by an identical right-hand structure (not shown). A pair of spaced parallel arms 327 and 327A secured to plate 318 and extending inwardly thereof contain openings 328 for the reception of a bolt therethrough to either engage chain 70 or chain 74 as may be desired, the bolt 78 being shown engaging chain 70 for helical winding.

Carriage 50 is provided with a filament handling member 340 which is pivoted to plate 318 by hinge members 342, 342. An inverted U-shaped frame 344 is mounted on the top of member 340 and supports eye guide 346 for the filament. A frame 348 secured to the lower end of member 340 supports a conventional basin resin applicator 350 through which filaments pass. Filaments pass downwardly through ring guide 352 and then to the mandrel. Carriage 60 is identical with carriage 50 and hence need not further be described.

In certain instances it is desirable to be able to rapidly cause the carriages to selectively engage and disengage the chains from a remote control point in lieu of using the simpler mechanical arrangement of bolts. This can readily be accomplished by securing to each carriage a pair of automated chain-engaging members, one for each chain. Such a chain-engaging member is shown in FIGURE 5 and denoted by the numeral 360 and comprises a vertically movable slide 362 having a reduced end 364 adapted to pass between a pair of adjacent links of a chain, for example chain 70. Slide 362 is provided with

5

a slot 366 engaged by pin 368 secured to bar 370 which is in turn secured to solenoid plungers 372 and 374 at 376 and 378, respectively. Plunger 372 is an integral part of solenoid 380 and acts to move bar 370 to the left as viewed in FIGURE 5 when solenoid 380 is actuated. Plunger 374 is an integral part of solenoid 382 and acts to move bar 370 to the right as viewed in FIGURE 5 when solenoid 382 is actuated. As viewed in FIGURE 5, the actuation of solenoid 382 will move pin 368 to the right causing it to advance through slot 366 and hence move slide 362 downwardly to cause reduced portion 364 to pass between adjacent links of chain 70. Conversely when solenoid 380 is actuated, bar 370 and pin 368 will be moved to the left causing slide 362 to be moved upwardly clear of chain 70.

Operation

FIGURE 1 illustrates a typical operation of the above-described filament winding machine. As shown in FIGURE 1, a cylindrical tubular object 12 having opposite domed ends has been partially formed. Both carriages 50 and 60 are advancing from left to right as shown in FIGURE 1 with carriage 60 laying down a band of resin impregnated glass filaments in so-called level windings and carriage 50 laying down a band of resin impregnated glass filaments in so-called helical windings.

Mandrel 10 and hence tubular object 12 is continuously rotated in a clockwise direction as viewed from the right-hand end of the apparatus shown in FIGURE 1. This rotation is achieved by means of hydraulic motor 14 which is set to the desired speed of rotation by means of control valve 16. Hydraulic motor 14 drives sprocket 18 which in turn drives chain 20 and sprocket 22 secured to shaft 24. Shaft 24 drives sprocket 26 which in turn drives chain 28 which drives sprocket 30 secured to shaft 32. Head stock 4 is driven by shaft 32 and engages a rod 8 secured to mandrel 10. Similarly, shaft 24 drives sprocket 34 and hence chain 36 which drives sprocket 38 to drive shaft 40 and tail stock 6 which engages a rod 8 at the opposite end of mandrel 10. Thus, mandrel 10 is rotated in a clockwise direction as viewed from the ring-hand end of the apparatus shown in FIGURE 1.

Referring now to carriage 50, it is advancing to the right as shown in FIGURE 1 by virtue of the engagement of chain 70 by bolt 78 causing carriage 50 to be moved therewith. Chain 70 is driven by hydraulic motor 104 through gear box 102, sprocket 100, chain 98, sprocket 96, shaft 94 and sprocket 99. When the left-hand edge of the band of filament being laid by carriage 50 (as viewed in FIGURE 1) reaches the end of the cylindrical portion of tubular object 12, pin 144 which has been moving upwardly as viewed in FIGURE 2, will arrive at the point where chain 146 is substantially tangent to sprocket 148. From these positions, carriage 50 will continue to move at the same rate to the right while plate 142 will shortly thereafter commence moving at a slower rate due to the fact that pin 144 is moving about the arc of sprocket 148. This results in a reduction in the rate of paying out of cable 132. Since cable 200 attached to carriage 50 is moving at its original rate and hence through drum 206, gear 210, gear 212 and gear 214 and shaft 216 are rotating drum 134 clockwise as viewed in FIGURE 2 at the original rate and hence winding up cable 132 on drum 134 at the original rate. Since cable 132 is being moved at a slower rate by carriage 140 and coiled up on drum 134 at the original rate, there is a resultant elevation of pulley 130 and lever 118 causing lever 112 to pivot and move lever 108 to the right causing servo-valve 106 to place the hydraulic motor in a neutral, i.e. non-rotating, condition and thus stop the travel of carriage 50. At this stage there is no substantial motion of cable 132 or drum 134. As pin 144 moves around sprocket 148 and commences to move downwardly as shown in FIGURE 2, it commences to move plate 140 downwardly causing movement of cable 132 away from

6

drum 134. Since drum 134 is stationary, this causes a further elevation of pulley 130 and lever 118 and further rotation of lever 112 to urge lever 108 further to the right and cause servo-valve 106 to cause hydraulic motor 104 to operate in the direction the reverse from its original direction of motion, thus causing the direction of travel of carriage 50 to be reversed from its original direction of travel. The parts are so selected that the dwell or non-motion period of carriage 50 will be such that mandrel 10 will have rotated tubular body 12 generally about 180° depending upon the conformation of the band filament desired, all of which is well known to those skilled in the art.

When carriage 50 reaches the left-hand end of the tubular portion of object 12 as viewed in FIGURE 1, a similar result is achieved in the same manner. As pin 144 reaches and passes the point of tangency of chain 146 with sprocket 150, the rate of movement of cable 132 slows while the cable is being unwound due to the movement of carriage 50 from drum 134 at the original rate. This causes a lowering of pulley 130 and lever 118 to permit the counterclockwise movement of lever 112 and movement of lever 108 to the left as viewed in FIGURE 2 causing servo-valve 106 to place motor 104 in the neutral condition thus causing the arresting of the movement of carriage 50. As pin 144 passes around sprocket 150 and reverses direction, plate 140 causes the movement of cable 132 towards drum 134 causing a further lowering of pulley 130 and lever 118 and further movement of lever 112 counterclockwise to pull lever 108 towards the left as viewed in FIGURE 2 causing servo-valve 106 to place hydraulic motor 104 in a condition for rotation in the original direction to move carriage 50 to the right as viewed in FIGURE 1.

In the meantime, a level winding of a band of filaments 54 has been accomplished by carriage 60 which is moving to the right as viewed in FIGURE 1. Switch 278 and relay switch 274 are in the closed position, the latter being held in the closed position by coil 276 which is connected to line 270 by line 279 and to line 264 at 277 in a typical holding circuit arrangement. Line 264 thus has solenoid 260 in the energized position which has the clutch-reversing mechanism in a position to cause the driving of carriage 60 to the right as viewed in FIGURE 1 by virtue of drive from hydraulic motor 14 through gears 18 and 20, shaft 24, sprocket 188, chain 186, sprocket 184, sprocket 256, chain 254, sprocket 252 and gears 250, 248 and 246 and shaft 244, the clutch-reversing mechanism 242 driving shaft 240, the gears in gear box 238, shaft 237, sprocket 236 and chain 234 which drives sprocket 232, shaft 230 to which is secured sprocket 228, drive chain 76 which is connected to carriage 60 by bolt 80. Carriage 50 will make numerous passes while helical winding for each pass of carriage 60. When the band of filaments 54 being laid by carriage 60 reaches the end of the tubular portion of tubular object 12, carriage 60 engages switch 278 opening it. This causes the deenergizing of line 270 and the consequent deenergizing of coil 276, and hence the opening of relay 274, to deenergize solenoid 260. This in turn causes the clutch-reversing mechanism 242 to declutch and re clutch in the reverse position to cause the reversal of the direction of movement of chain 76 and the consequent reversal of movement of carriage 60. As carriage 60 moves away from switch 278, it closes. When carriage 60 reaches a point where the band of filaments is at the left-hand end of the tubular portion of tubular object 12, it engages switch 266 which is normally open to close it and thus energize coil 276 to close relay 274 and to energize solenoid 260 to declutch and re clutch for movement in the reverse direction the clutch-reversing mechanism 242 which thus causes the movement of chain 76 in the reverse direction carrying carriage 60 to the right as viewed in FIGURE 1. As the carriage 60 moves away from switch 266 it opens but solenoid 260 remains ener-

gized by virtue of the continued energization of coil 276 since it is connected at 277 to line 264 and to line 270 by line 279.

From the above typical operation, it will be appreciated that a wide variety of filament winding patterns can be achieved. Innumerable possibilities are provided by the fact that both carriages 50 and 60 can be selectively connected to chains 70 and 72 respectively for helical winding and to chains 74 and 76 for level winding. While the various patterns of filament winding with various combinations employing helical and/or level windings are well known to the art, it will be evident that the above described apparatus provides a highly advantageous means for achieving the various patterns.

Variations in the lead angle of filaments 54 being wound on the mandrel from carriage 50 can be achieved by varying the angles which the runs of chains 146 make with slot 142. Thus, for example, chain 146 can run the position shown in phantom in FIGURE 2 by adjustment of the positions of arms 154 and 159 and the relative positions of sprockets 148 and 150 on said arms. In the position shown in phantom, it is apparent that chain 146 will advance plate 140 at a slower rate than the advancement caused when the chain is in the position shown in full lines in FIGURE 2. This in turn through the action of wire 132 and its associated linkage will be translated to servo-valve 106 which in turn will regulate the hydraulic motor 104 so as to slow down the rate of travel of chains 98 and 70 to correspondingly slow down the travel of carriage 50 which results in a smaller lead angle for the filaments. This adjustment can be used, for example, to good effect where it is necessary to very accurately maintain a lead angle of 45° throughout winding of a relatively thick tube, i.e. one having a substantial difference between the inner diameter and the outer diameter. Thus, if chain 146 in the position shown in phantom in FIGURE 2 provides a lead angle of 45° for the inner diameter of a particular tube, by gradually reducing the angle which the runs of chains 146 make with slot 142 as the thickness of the tube increases, the speed at which the carriage 50 travels can be gradually increased so as to keep lead angle of the filament at 45°.

While discussing lead angle, it is worth pointing out that the use of a computer to control the carriage for helical winding rather than having a non-computerized direct drive has a very great advantage where a small lead angle is employed. To achieve a small lead angle such as, for example, 25° chain 146 must move at a relatively high speed which cuts down the dwell time at the end of the carriage travel as pin 144 moves around the outside end of the sprockets 148 and 150. A controlled dwell time is readily achieved by adding a second sprocket 148 on arm 154 and a second sprocket 150 on arm 159 and employing a longer chain 146' which passes around both sprockets 148, 148 and sprockets 150, 150 and carries a pin 144' which engages slot 142 in carriage 140 as shown in FIGURE 6. This arrangement permits an accurate control of the length of travel of carriage 50 and an equally precise control of the dwell time before the carriage reverses itself in each direction.

What is claimed is:

1. A filament winding machine comprising a mandrel, means to rotate the mandrel at a predetermined speed, a pair of opposed carriages mounted for reciprocation above the mandrel in the direction of the length of the mandrel, a pair of endless chains adjacent each carriage, means to drive one chain of each pair of chains at a relatively slow speed for level winding and means to drive the

other chain of each pair of chains at a higher speed for helical winding, means to selectively secure each carriage to either of its adjacent chains, and means to reverse the direction of travel of each chain at predetermined intervals.

2. A filament winding machine comprising a mandrel, means to rotate the mandrel at a predetermined speed, a filament guiding carriage mounted adjacent the mandrel for reciprocation in the direction of the length of the mandrel and means to reciprocate the carriage at a predetermined rate including an analog device reproducing on a reduced scale the desired movement of said carriage, feed back means connected to the carriage and control means responsive to the output of the analog device and the feed back means to cause the carriage to follow the movement of the analog device, the analog device including an endless chain mounted on a pair of opposed sprockets, a pin secured to the chain and a member mounted for reciprocation and having a track normal to the reciprocation engaged by said pin and means to drive one of said sprockets.

3. A device in accordance with claim 2 in which means are provided to adjustably mount the sprockets to provide for the adjustment of the angular relationship between the track and the reaches of the chain.

4. A filament winding machine comprising a mandrel, means to rotate the mandrel at a predetermined speed, a filament guiding carriage mounted adjacent the mandrel for reciprocation in the direction of the length of the mandrel and means to reciprocate the carriage at a predetermined rate including a reversible motor and a mechanical analog device reproducing on a reduced scale the desired movement of said carriage, mechanical feed back means connected to the carriage and control means responsive to the output of the analog device and the feed back means to control the motor to cause the carriage to follow the movement of the analog device, the analog device including an endless chain mounted on a pair of opposed sprockets, a pin secured to the chain and a member mounted for reciprocation and having a track normal to the reciprocation engaged by said pin and means to drive one of said sprockets.

5. A device in accordance with the claim 4 in which means are provided to adjustably mount the sprockets to provide for the adjustment of the angular relationship between the track and the reaches of the chain.

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