FILAMENT WINDING

Original Filed Sept. 20, 1968

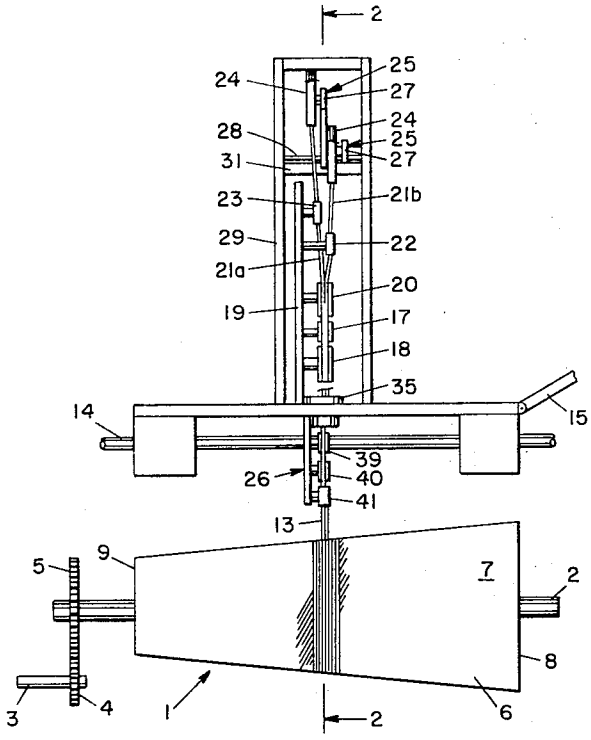

FIG. 1

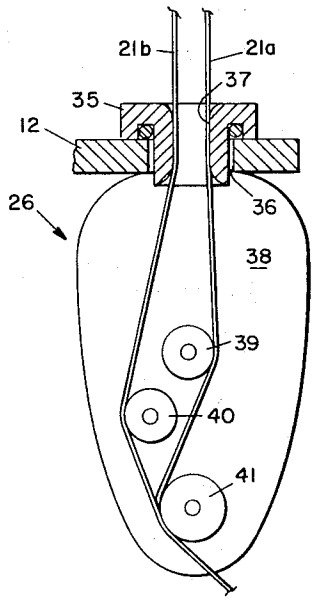

FIG. 3

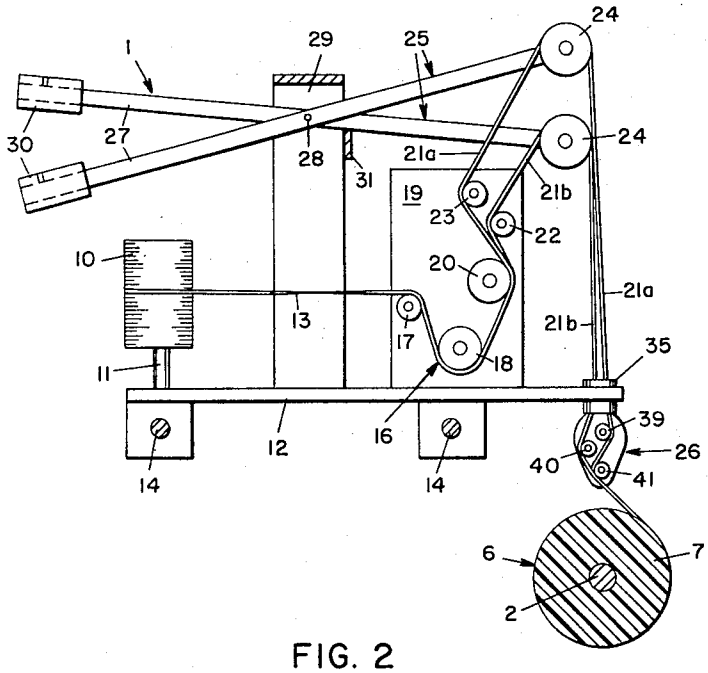

FIG. 2

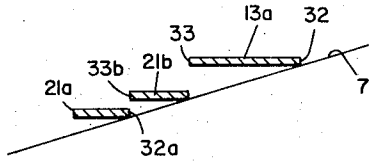

FIG. 4

United States Patent Office 3,707,415 Patented Dec. 26, 1972

3,707,415

FILAMENT WINDING

Arthur D. Golladay and Kevin E. Moran, Cumberland, Md., assignors to Hercules Incorporated, Wilmington, Del.

Original application Sept. 20, 1968, Ser. No. 761,277, now Patent No. 3,565,726, dated Feb. 23, 1971. Divided and this application Oct. 9, 1970, Ser. No. 79,697
Int. Cl. B65h 81/08
U.S. Cl. 156—169 3 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to filament winding and particularly to winding pre-impregnated tape-like filamentary material on non-cylindrical surfaces, and comprises a cutter for splitting the tape endwise into a plurality of filamentary elements and means for effecting a take-up action individually upon each element, thereby reducing the shingling effect inherent in winding a tape on a curved surface.

This application is a divisional of application Ser. No. 761,277, filed Sept. 20, 1968, now U.S. Pat. No. 3,565,726.

The present invention relates to a method for making filament wound articles from tape-like filamentary materials and particularly for making filament wound articles having non-cylindrical or curved surfaces.

In order for a filament winding operation to proceed at a speed that is commercially economical, the filaments are laid on the winding surface as tapes rather than as individual filaments so that in a single turn of the winding surface the number of filaments laid on the winding surface is equal to the number of filaments in the width of the tape. However, in using a tape-like filamentary material to wind a non-cylindrical article such as an article having a conical surface, there are variations in the diameter of the windnig surface across the width of the tape. Thus, the length of the path on the winding surface followed by the different transverse increments of the tape vary between a path of maximum length at one edge of the tape and a path of minimum length at the other edge of the tape. For example, in winding a conical surface with the tape running spirally from the large end of the cone to the small end, the path on the winding surface that is followed by the edge of the tape that is toward the small end of the winding surface is shorter than the path followed by the opposite edge of the tap. There is thus an excess length in the filaments at the edge following the minimum length path. Because of this excess length, this edge is loose and stands out from the winding surface in what may be termed a shingling effect. This looseness causes voids in the wound structure and reduces the strength of it.

In filament winding operations, handling and accurately laying a relatively wide tape-like arrangement of individual filaments is facilitated by preforming the filaments into a coherent tape that is bound together by the binding material used for binding the filaments in the wound structure, which binding material is pre-impregnated and partially cured. In contrast to a preimpregnated tape, in a winding operation in which the filaments are assembled into a band and impregnated with the resinous binding material as it is being wound, the filaments are loose and it is difficult to control them accurately enough as they are laid on the winding surface in order to avoid overlapping of the filaments and gaps between adjacent filaments, or other void-producing winding errors. When the filaments are pre-formed into tapes consisting of a plurality of filaments, for example in a single layer of filaments in a side-by-side relation, winding errors are reduced since it is necessary only to lay the adjacent tapes in edge-to-edge relation on the winding surface.

The objects of this invention are to provide a method for making filament-wound structures of non-cylindrical configuration, which method and apparatus is capable of relatively high production rates and will inexpensively produce high quality wound structures with a minimum of voids and winding errors. Further objects of this invention will be evident from an understanding of the invention as hereinafter described.

Briefly, the above objects have been achieved by using filaments in the form of a pre-impregnated tape in which the individual filaments are bound together by the partially cured binding material. The tape may be of sufficient width to provide for an economical winding operation but, prior to winding, is divided into a plurality of narrow winding strips. The shingling effect produced by the difference in the diameter of the winding surface over the width of the tape is thus reduced. The accumulated difference in the lengths of the winding paths of the different winding strips is withdrawn from the system by take-up devices and stored until the end of the winding cycle, at which time it is cut off to restore the tape to a starting condition before initiating the next cycle.

With the above and other objects in view, the present invention is hereinafter described with reference to the accompanying drawings, in which:

FIG. 1 is a fragmentary elevational view of a winding apparatus embodying the present invention.

FIG. 2 is a fragmentary sectional view taken substantially on the line 2—2 of FIG. 1.

FIG. 3 is a fragmentary detail view showing the tape guide of the apparatus of FIG. 1.

FIG. 4 is a diagrammatic view illustrating the tape-laying operation of this invention.

With reference to the drawings, there is illustrated a winding machine **1** having a rotating winding shaft **2** that is driven by a drive shaft **3** having a gear **4** that meshes with a gear **5** on the shaft **3**. Mounted on the shaft **3** and rotatable therewith is a mandrel **6**. As ilustrated, the mandrel **6** is substantially frustroconical in shape with the winding surface **7** thereof decreasing in diameter from the large diameter end **8** to the small diameter end **9**.

The filamentary winding material that is to be wound on the winding surface **7** of the mandrel **6** is supplied in the form of a tape **13** from a spool **10** that is mounted on a spool pin **11** upstanding from a platform **12** of a tape feed mechanism. The spool **10** is loose on the pin **11** so that it is free to turn as the tape **13** is pulled from it. The platform **12** is mounted for sliding endwise or axially of a pair of rods **14** that are disposed parallel to the axis of the winding shaft **2**, and which define the tape-laying axis along which the tape feed mechanism is moved. The platform **12** is adapted to be driven along the rods **14** by a drive link **15** that may be actuated by a programmed mechanism (not shown) whereby the platform will traverse the mandrel **6** and the tape **13** is laid onto the winding surface **7** in accordance with a pre-determined pattern.

From the spool **10**, the tape **13** passes through a tension device **16** that consists of a guide pin **17** and a frictioning drum **18**, both of which are supported on a supporting plate **19** upstanding from the platform **12**. In order to adjust the drag on tension imposed upon the tape **13**, the pin **17** may be adjustable (not shown) to increase or decrease the angle of engagement between the tape **13** and the drum **18**, or alternatively, the drum **18** may be provided with a rotatable shaft (not shown) having an adjustable brake mechanism for imposing a drag thereon. In either case, the surface of the drum **18** may be provided with a frictioning material.

The tape **13** passes from the drum **18** over a cutter **20** which may be in the form of a rotary blade that is journaled on the supporting plate **19**. The cutter **20** splits the tape **13** longitudinally substantially along its centerline, into the winding strips **21***a* and **21***b*, each having a width substantially equal to one-half the width of the tape **13**. From the cutter **20**, the strips **21***a* and **21***b* pass individually over one of a pair of guide pins **22** and **23**, over a guide roller **24** of individual take-up devices **25**, through a guide **26** carried by the platform **12** and onto the winding surface **7** of the mandrel **6**.

There is a separate take-up device **25** for each of the strips **21***a* and **21***b*, each of which take-up devices comprises a bar **27** pivoted intermediate its end on a pivot **28** carried by a support **29** upstanding from the platform **12**. The guide roller **24** is mounted for turning freely upon one end of the bar **27** while the other end of the bar **27** carries a weight **30** that is adjustable lengthwise of the bar and adapted to be secured in adjusted position. The weight **30** imposes a pivotal bias on the bar **27** in the direction whereby the roller **24** effects a take-up action on the length of the respective strip **21***a* or **21***b* that is between the mandrel **6** and the drum **18**, thus removing and temporarily storing any excess length of the strips that may be present.

In operation, rotation of the mandrel **6** pulls the strips **21***a* and **21***b* taut against the drum **18** of the tension device **16**, which initially lowers the take-up bars **27** into their stop positions as determined by a stop **31** on the bracket **29**, and then pulls the tape **13** from the spool **10** and through the tension device **16**. As the tape **13** advances from the tension device **16**, it passes over the cutter **20**, which splits it longitudinally into the two winding strips **21***a* and **21***b*, each of which then passes individually over the roller **24** of the respective take-up device **25** and onto the mandrel **6**.

With reference to FIG. 4, if the tape **13** were laid as an unsplit tape **13***a* onto the winding surface **7**, there would be what is herein referred to as a tight edge **32**, which is the edge at the largest diameter of the winding surface **7** over the width of the tape **13** and therefore the edge that follows the maximum length path on the winding surface **7**. The edge **32** is drawn against the surface **7** by a force determined by the tension device **16**. The opposite edge of the tape **13***a* constitutes a loose edge **33** which, because the diameter of the winding surface **7** at this point is reduced relative to the diameter at the edge **32**, and because the length of the tape **13***a* drawn from the spool **10** is determined by the engagement of the tight edge **32** with the surface **7**, stands out from the surface **7** by a distance determined by the slope of the surface **7** over the width of the tape **13***a*. Because of the reduced diameter of the winding surface **7** under the edge **33**, the projection of this edge into the winding surface **7** as the latter rotates defines a path on the winding surface that is shorter than the path defined by the edge **32** so that there is an excess length at the edge **33**. By splitting the tape **13***a* along its centerline into the two winding strips **21***a* and **21***b*, and by effecting a take-up action individually on the strips, there is removed from the system the accumulated excess length at the centerline of the tape, which is now the loose edge **33***b* of the strip **21***b*, as the leading edge **32***a* of the strip **21***a* is drawn against the winding surface to form a new tight edge.

Accordingly, as the winding operation proceeds, the take-up device **25** associated with the strip **21***a* moves away from the stop **31** as it accumulates the excess length of that strip. At the end of a tape-laying cycle, which may be one or more passes across the winding surface, the accumulated excess is removed and discarded as waste. During the accumulation of the excess, the tape **13** is pulled from the spool **10** by the mandrel **6** through the strip **21***b*, the bar **27** associated with this strip being maintained against the stop **31**.

The guide **26** is designed to separate the two filamentary strips **21***a* and **21***b* and to keep them separated until immediately before they are laid on the winding surface **7**, thus minimizing the possibility that they may inadvertently come into contact and become adhesively secured together. Therefore, the guide **26** comprises an eye **35** that is mounted on the platform **12** for rotation relative thereto and having a shank portion extending down through an aperture **36** in the platform **12**, the eye having a guide opening **37** centrally thereof. Beneath the platform **12**, there is secured to the eye **35** a support plate **38** on which are journaled a pair of spaced guide rolls **39** and **40** and a delivery roll **41** at which the two strips **21***a* and **21***b* are rejoined in edge-to-edge relation. With the eye **35** mounted for turning freely in the platform **12**, that is, about its vertical axis in FIG. 3, the delivery roll **41** is free to align itself with the delivery angle of the tape.

While the tape **13** is the illustrated embodiment of the invention is divided into two strips **21***a* and **21***b*, it will be obvious that it may be divided into several strips, thus further reducing the width of the individual winding strips and the spacing of the loose edges of them from the winding surface. By way of example, a tape **13** that is initially one eighth of an inch in width may be split into four winding strips, each of which is one thirty-second of an inch in width. The excess length accumulated at the loose edge in winding a conical surface, which excess is prohibitive with a tape that is one-eighth inch wide, is reduced to acceptable limits with winding strips that are one thirty-second inch wide. At the same time, the advantages associated with feeding a plurality of filaments simultaneously in a tape onto a winding surface, that is, the increased winding speeds and reduced winding errors, are not materially sacrificed. While the filaments are preferably bound into a coherent tape as in the usual pre-impregnated tapes used in filament windings, the present invention is also useful with noncoherent tapes.

The cutter **20** is preferably a rotary cutting blade but may also be a flat blade such as a razor blade or may be a wire. Inasmuch as the tape **13** consists essentially of filaments extending in an oriented or parallel relation lengthwise of the tape and interconnected laterally only by the partially cured binding material, which is relatively weak, the tape can be split lengthwise relatively easily. Thus, a cutter **20** in the form of simple wires can also be used.

The winding tension on the strip **21***b* is determined essentially by the force required to pull the tape **13** through the tension device **16**, while the take-up device **25** associated with the strip **21***b* becomes in effect a fixed guide since it is held in a stop position with the bar **27** against the stop **31**. The strip **21***a* is loose except for the tension imposed upon it by the respective take-up device **25**, and this tension is preferably made as close as possible to that on the strip **21***b*. Since the tension on the strip **21***a* also tends to pull the tape **13** through the tension device **16**, it is preferably adjusted to substantially one-half the force required to pull the tape through the tension device **16** so that the tensions on the strips **21***a* and **21***b* are substantially balanced. The tension on the strip **21***a* is adjusted by adjustment of the weight **30** lengthwise of the bar **27**. It will be obvious that the bias of the bar **27** may be achieved by means other than the weight **30**, for example, by an air cylinder or spring. A further alternative would be a positive feed of the capstan type which feeds the band of tape into the system in response to an increment of tension over and above the normal winding tension.

What we claim and desire to protect by Letters Patent is:

1. A method of making a filament wound structure from a tape of filamentary material wound upon a rotating winding surface on which the winding path of the tape on the winding surface varies in length over the width of the tape from a maximum winding path at one

edge of the tape to a minimum winding path at the other edge of the tape, comprising, advancing the tape toward the winding surface, dividing the tape into a plurality of longitudinal narrow strips, winding said strips in accordance with a winding pattern onto the winding surface, simultaneously taking up under tension and accumulating the excess length from each of the strips that has a winding path shorter than the maximum winding path, and periodically removing the accumulated excess length of strips.

2. A method in accordance with claim 1 in which the filamentary tape is pre-impregnated with a binding material that is partially cured to bind and thereby render the same coherent.

3. A method in accordance with claim 1 in which

substantially constant tension is applied to each of the narrow strips.

References Cited

UNITED STATES PATENTS

2,594,693	4/1952	Smith	156—175 X
3,506,420	4/1970	Jackson, Jr., et al.	156—167 X
3,290,197	12/1966	Carmody	156—175 X

DANIEL J. FRITSCH, Primary Examiner

U.S. Cl. X.R.

156—172, 173, 189, 195, 259, 264, 271