Nov. 5, 1968 J. H. WASSERLEIN 3,409,243

WINDING APPARATUS

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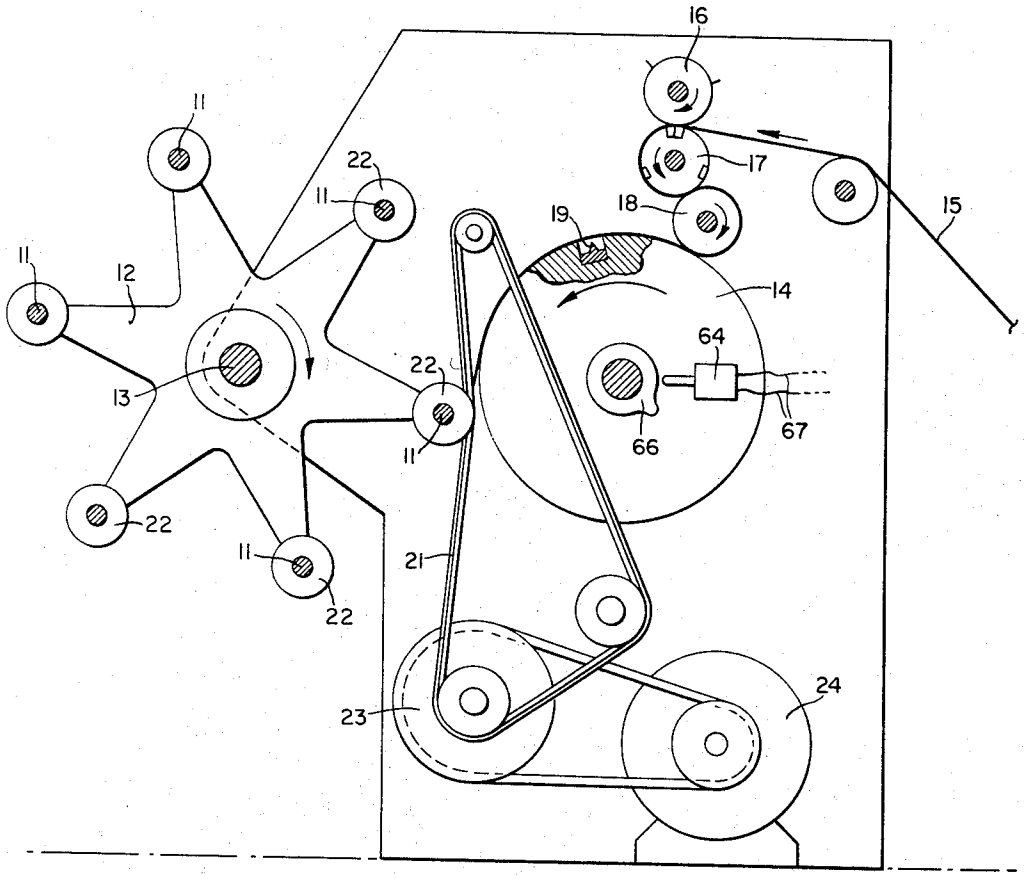


Fig. 1

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Nov. 5, 1968 J. H. WASSERLEIN 3,409,243

WINDING APPARATUS

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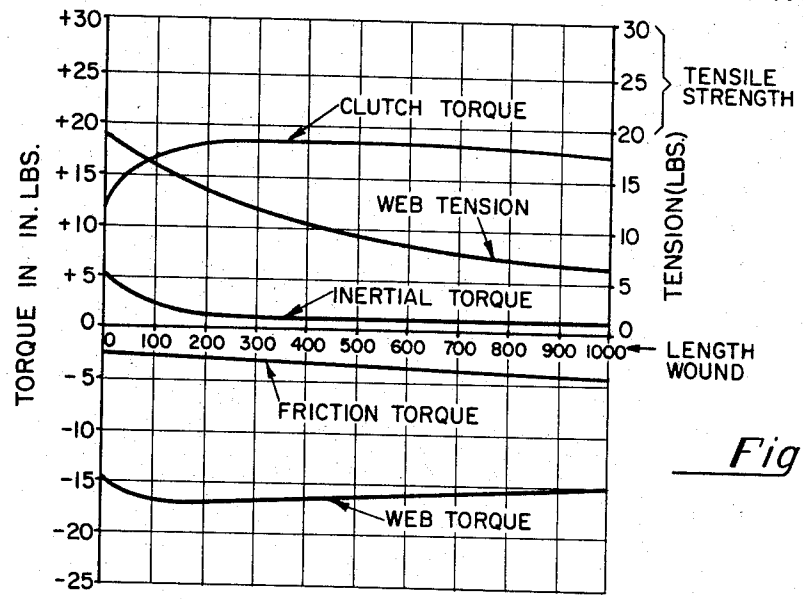


Fig. 2

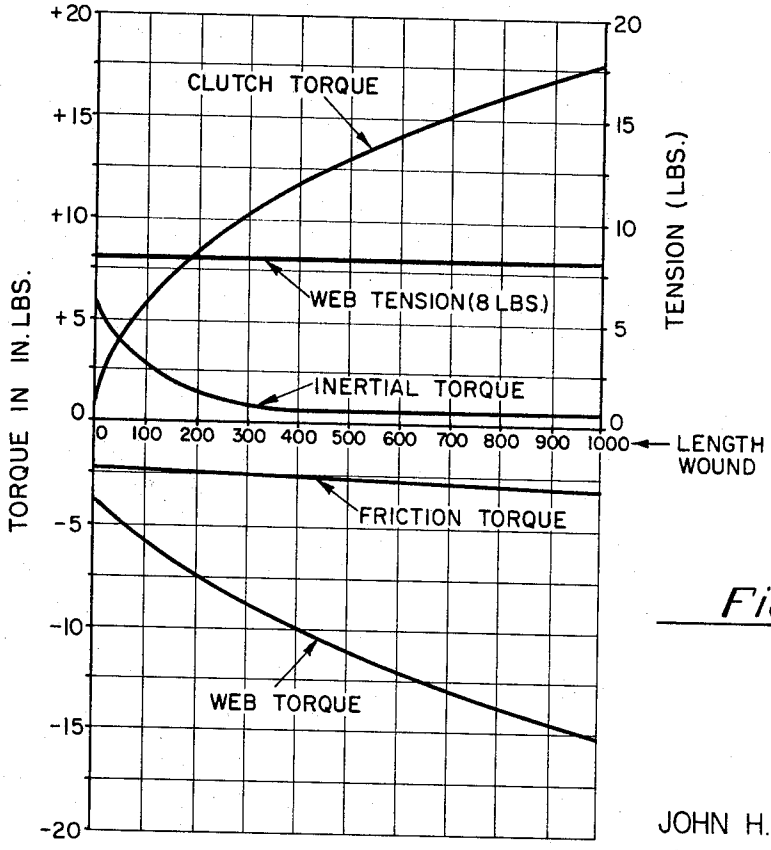


Fig. 3

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WINDING APPARATUS

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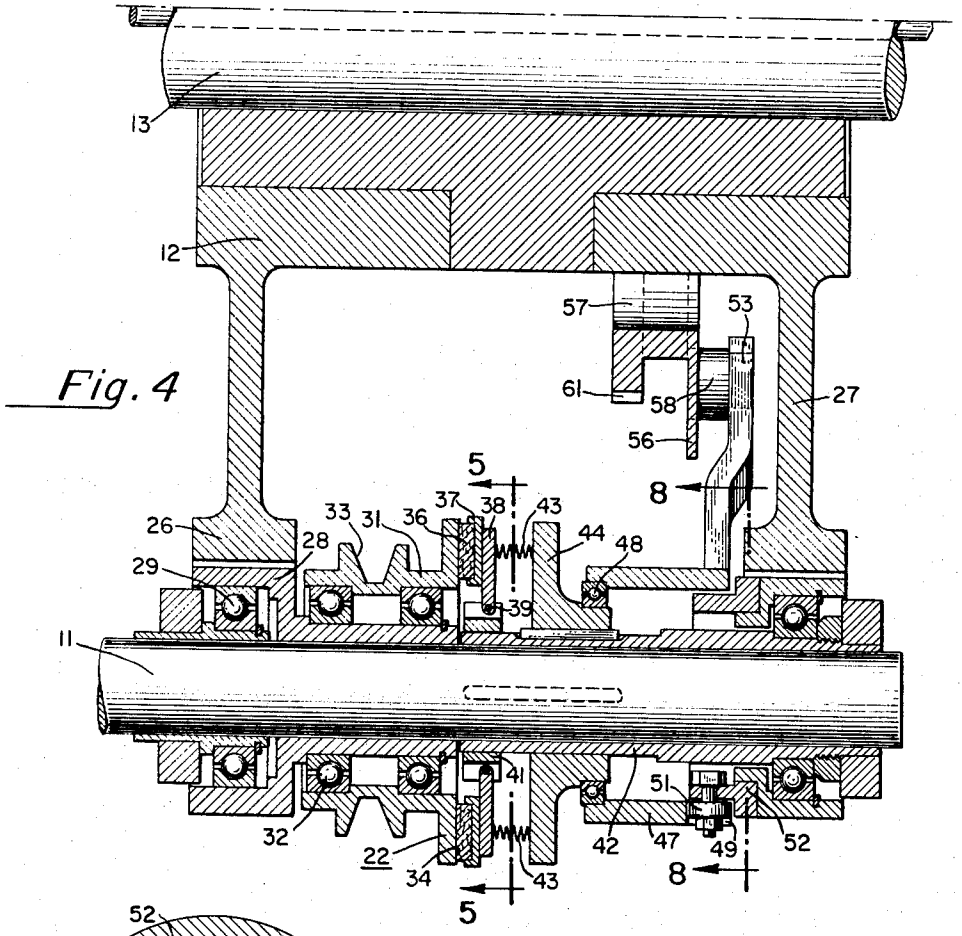


Fig. 4

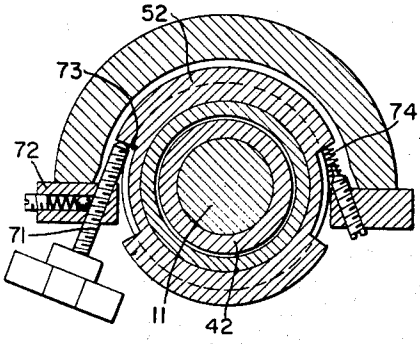


Fig. 8

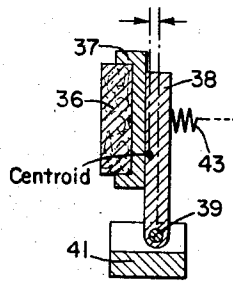


Fig. 6

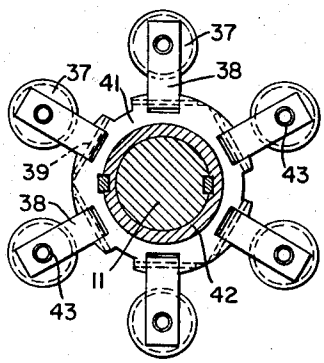


Fig. 5

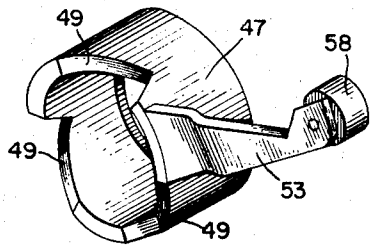


Fig. 7

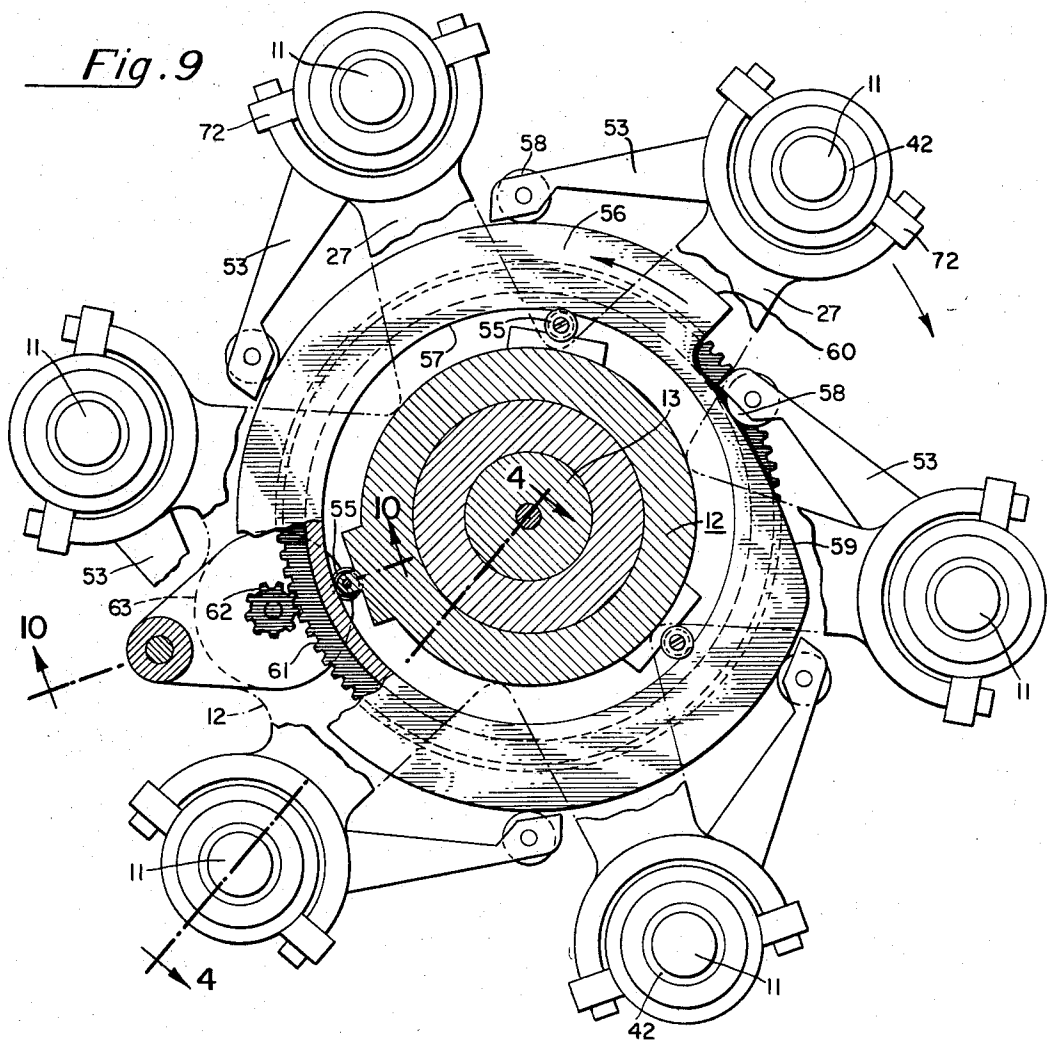
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WINDING APPARATUS

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Fig. 9



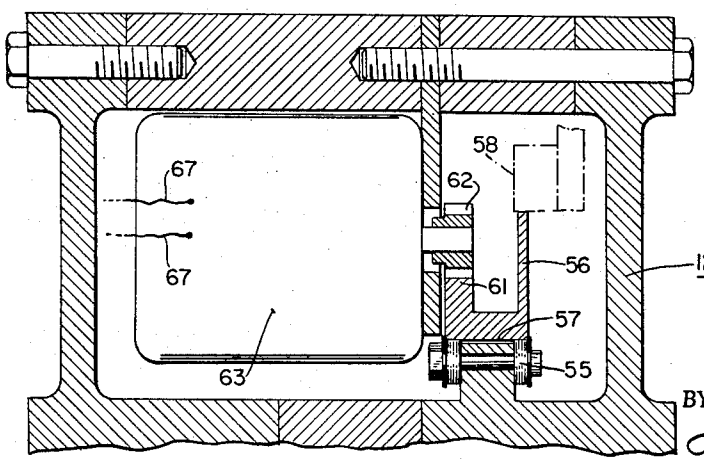


Fig. 10

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WINDING APPARATUS

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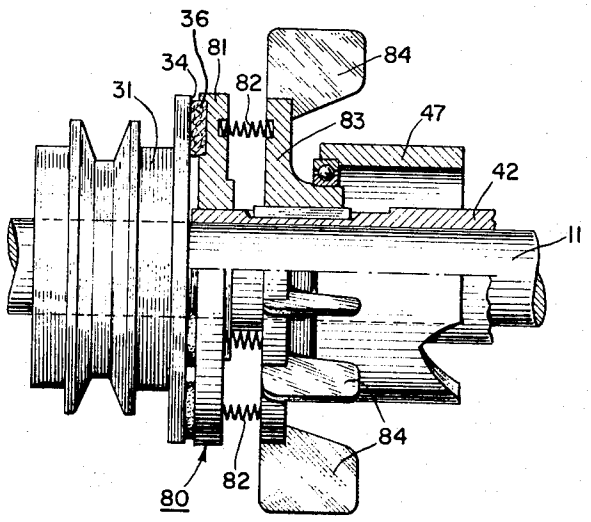


Fig. 11

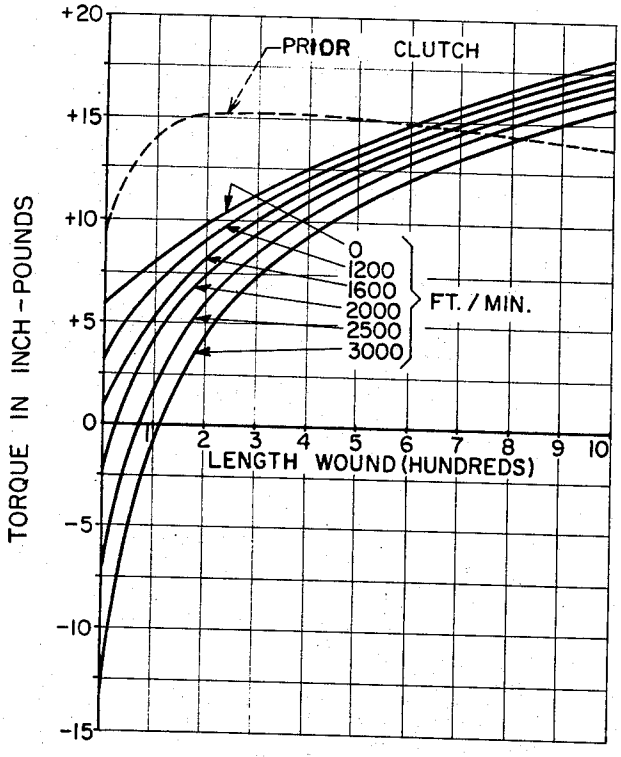


Fig. 12

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United States Patent Office

3,409,243

Patented Nov. 5, 1968

3,409,243

WINDING APPARATUS

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Filed Feb. 8, 1965, Ser. No. 431,016
7 Claims. (Cl. 242—64)

ABSTRACT OF THE DISCLOSURE

High speed web winding apparatus is disclosed which is adapted for turret type winders to control tension applied to the web being wound. The apparatus responsively adjusts the torque transmitted by a drive motor to a winding mandrel to reflect various changing torque conditions existing during the progress of the wind of a web into a roll upon a core carried on the mandrel. In addition to a rotatable mandrel on which the web is to be wound, a drive means, and a clutch for transmitting torque from said drive means to said mandrel, the apparatus includes means responsive to the velocity of said mandrel as a function of the square of the velocity of the mandrel and, in addition, program means responsive to the progress of a wind on said mandrel and acting on said clutch for progressively controlling the torque transmitting ability of the clutch during the web wind. For example, one embodiment of the apparatus employs means, such as the combination of a centrifugally actuated clutch system and a cam system for superimposing a program control upon the clutch system, which means cooperate to properly compensate for changing torque conditions in the winding system in order to maintain substantially constant web tension during the progress of the wind.

This invention relates to winding apparatus and more particularly to apparatus for winding lightweight webs, or tapes, at high speeds.

It is common practice in the production of lowcost roll items, such as toilet tissue, to employ high speed equipment in which the rolls are wound on a series of movable mandrels which are successively brought into winding position to commence a winding operation immediately after the completion of the preceding winding operation and without stopping or slowing the incoming web of material. Attempts are constantly made to operate winders of this type at increasingly higher speeds in order to render the operation more economical. Although elaborate control systems have been developed through the years, high speed operations of such machines have always been replete with problems of web breakage, particularly when winding low strength materials, such as paper.

Obviously, web breaks occur during winding when the tension to which the web is subjected exceeds the tensile strength of the web material. In high speed winding machines it is difficult to sense the tension existing in the web during the wind, primarily because of space limitations within the machine. More commonly, a clutch is imposed between the drive and the winding mandrel to limit the amount of torque imparted to the mandrel and thereby indirectly limit the tension to which the web is subjected. The use of such a clutch offers the further advantage of permitting the mandrel to slow down during the wind as the roll grows so that the web can be wound at constant speed while the mandrel is driven from a constant speed drive. An automatic winding machine incorporating these features is disclosed in U.S. Patent No. 2,769,600 to Kwitek et al.

It is the principal object of this invention to improve the operation of the aforementioned type of winding equipment so that the winding operation may be performed at higher speeds and/or with less frequent web breakage.

I have discovered by investigation and analysis that machines equipped with clutches for driving the winding mandrels subject the web to large variations in tension during the course of the wind. I have further discovered that these extreme variations of tension in the web are the result of the machine's failure to take into account and compensate for the various torque conditions existing during the wind. In particular, such machines, in the past, have disregarded or failed properly to take into account the inertial torque caused by deceleration of the winding mandrel and the wound web during the wind. It is, therefore, another object of this invention to provide means for varying the torque transmitting ability of a winding clutch to vary the applied torque in inverse ratio to the varying inertial torque present in the winding system. Inertial torque is the result of deceleration of the rotating system and is a function of the square of the velocity of the system. This invention, therefore, contemplates varying the torque transmitting ability of the clutch indirectly with the changes in the square of the angular velocity of the winding mandrel. For this purpose the invention employs means responsive to the angular velocity of the mandrel for reducing the torque imparted to the mandrel in inverse ratio to a function of the square of the angular velocity.

It is well known that if any degree of uniformity is to be maintained in the tension of the wound roll in a center drive winding operation it is necessary to increase the torque applied to the winding mandrel as the roll of material grows to offset the increasing moment arm through which the torque acts on the web being wound. In various prior art machines centrifugal force responsive clutch elements have been employed to progressively increase the torque imparted to the winding mandrel during the web wind. See, for example, U.S. Patent No. 2,901,192 to Nystrand. The use of a centrifugal clutch for this purpose has a number of drawbacks and limitations. The principal deficiencies are that the use of such a clutch does not produce the precise torque program required and is limited to the particular operating speed for which the clutch is designed. Any departure from the design speed results in the clutch transmitting more or less torque than is desired for winding at constant web tension.

It is a further object of this invention to program the torque imparting ability of a winder clutch to increase its torque imparting ability progressively as more web material is wound and the size of the wound roll grows. This program can, in accordance with this invention, also take into consideration other factors affecting web tension during the wind, such as torque conditions resulting from friction and windage in the system as well as such differences in torque profile characteristics as may exist between the actual intertial torque profile existing for the system and the torque profile of the speed responsive clutch control.

The principal features, then, of this invention reside in modifying the torque transmitting ability of a winder clutch, first, in accordance with changes in the square of the velocity of the winder mandrel and, second, in accordance with a predetermined program during the progress of the wind from start to finish. This combination of features of the invention permits webs to be wound either with constant tension throughout the wind or with any desired tension profile through the wind.

It is a further object of this invention to improve the reliability of winders employing a clutch by reducing the tendency for the clutch to undergo excessive slip prior to commencement of a web wind. In prior machines such slippage resulted in the winding surface of the mandrel not being brought up to web speed at the time the web

was transferred to the mandrel and the transfer could not be accomplished smoothly. This object is achieved by designing into the programming means for the clutch an override, or overload, to substantially increase the torque transmitting ability of the clutch and prevent slippage prior to web transfer.

These and other objects, advantages and features of the invention can be better understood from the following detailed description of the invention wherein reference is made to the accompanying drawings, in which:

FIG. 1 is a diagrammatic sectional view taken near one end of a winding machine of a type to which this invention is applicable;

FIG. 2 is a graphic illustration of various torque effects present and tension forces experienced by the web during a wind on a typcial prior art machine operating at the upper limit of its operating speed;

FIG. 3 is a graphic illustration similar to FIG. 2 illustrating conditions experienced in a winding machine incorporating this invention and operating at a comparable speed;

FIG. 4 is a sectional view through a clutch for one of the mandrels of the machine illustrated in FIG. 1;

FIG. 5 is a transverse sectional view of the clutch taken as indicated by line **5—5** in FIG. 4;

FIG. 6 is an enlarged sectional view of a pad arm component of the clutch shown in FIG. 4;

FIG. 7 is a perspective view of a clutch adjusting sleeve employed in the clutch of FIG. 4;

FIG. 8 is a transverse sectional view taken as indicated by line **8—8** in FIG. 4 and illustrating an operator adjustment for the clutch;

FIG. 9 is an elevation view of one end of the turret assembly of the machine of FIG. 1 with portions of the turret broken away to illustrate various components of a clutch programming control;

FIG. 10 is a sectional view taken as indciated by line **10—10** in FIG. 9;

FIG. 11 is an elevation view, partially in section illustrating a modified clutch incorporating this invention; and,

FIG. 12 is a graphic illustration of the effect changing winding velocity has on torque required to be transmitted by a clutch in order to maintain constant tension in the web.

FIG. 1 illustrates a typical continuous winding machine employing a plurality of winding mandrels **11** rotatably carried by the arms of a turret **12** which, in turn, is rotatably supported by a shaft **13**. Suitable means (not shown) are provided for rotatively indexing turret **12** in clockwise direction for bringing succeeding mandrels **11** into winding position adjacent a rotatably mounted bed roll **14** over which a web **15** to be wound is fed. The web **15** may be directed to bed roll **14** through perforator rolls indicated at **16** and **17** and a feed roll **18**. During normal operation bed roll **14** is driven at a substantially constant velocity and as a roll of web material is completed on one of the mandrels **11** that mandrel is moved away from the bed roll and the succeeding mandrel is indexed into position near the bed roll, the web is severed and the leading edge of the severed web is transferred to a succeeding mandrel by suitable means, such as the retractable knife indicated at **19**.

In order to insure a smooth transition of web feed from one mandrel **11** to the next mandrel and to insure continuous feed of the web **15** during the wind it is essential that each mandrel as it approaches the winding position be rotatably driven to bring its winding surface up to the surface speed of bed roll **14** and subsequently, during the wind, be permitted to slow down to compensate for the growth of the roll being wound on the mandrel. The drive means illustrated in FIG. 1 is similar to that disclosed in the aforementioned Patent 2,769,000 and includes a moving flexible belt **21** positioned to engage a clutch mechanism **22** carried by each of the mandrels **11**. It will be noted that drive belt **21** engages a clutch **22** only when the mandrel for that clutch is approaching bed roll **14** or is in the vicinity thereof during the web wind. Belt **21** may be driven by any suitable means, such as the pulley and belt drive **23**, and a drive motor **24**. The other moving components of the winder, such as turret **12** and bed roll **14** may also be driven from motor **24**, but if driven by other motive sources their movements should be synchronized so that drive belt **21** is moving at a linear speed which will cause the surface velocity of a driven mandrel **11** to match the surface velocity of bed roll **14**.

Winding machines such as that illustrated in FIG. 1 often have incorporated therein slip clutches which permit the winding mandrel **11** to slow down during the web wind, notwithstanding the fact that drive belt **21** is propelled at a constant linear velocity. So called, "constant torque" clutches of this type limit the maximum amount of torque transmitted to their winder mandrels and are supposed to prevent the web from being subjected to excessive tension during the wind. In reality such clutches are ineffective to compensate for all factors influencing web tension and at higher winding speeds are totally ineffective to prevent web breakage.

Winding conditions

FIG. 2 illustrates what has been determined by laboratory investigation and analysis to be typical torque conditions and web tension conditions existing during the winding of a series of rolls of toilet tissue or a log of such tissue in a winder employing "constant torque" clutches. The line identified as "Clutch Torque" represents the torque which is actually transferred through the clutch **22** and applied to the winding mandrel **11**. For reasons which need not be discussed here there is a slight drop in the torque applied to the mandrel by the clutch at the beginning of the web wind. For all practical purposes, however, the torque transmitted is essentially constant throughout the wind. It will be noted that the web tension changes considerably during the web wind and is highest at the beginning of the wind (see curve labeled "Web Tension"). In the particular illustration of FIG. 2 the tension in the web at the beginning of the wind approaches 20 lbs., which is near the 20 to 30 lbs. tensile strength possessed by a perforated web of tissue paper for winding 20 rolls of toilet tissue. Consequently, any slight malfunction of the machine or non-uniformity of thickness or strength of the web can result in breaking the web at or shortly after the beginning of a wind.

FIG. 2 also illustrates one of the factors which contribute to high web tension at the beginning of a wind with existing winding equipment. Note the form of the curve identified as "Inertial Torque." This torque acts in the direction of rotation of the rotating mandrel and is the result of deceleration of the mass of the mandrel and the web being progressively wound thereon. It will be noted that the inertial torque is greatest at the beginning of the web wind when the mandrel is turning at very high rotative speed and is undergoing its maximum deceleration. The inertial torque of the wound web material, the mandrel and associated rotating equipment is a function of the square of the angular velocity of the rotating system as expressed in the following equation:

$$T_i = C\left[\frac{I_m + I_p}{R}\right]\omega^2$$

wherein,

C is a constant for the particular system, I_m is the moment of inertia of the mandrel and clutch,
I_p is the moment of inertia of the web wound,
R is the instantaneous radius of the building roll, and
ω is the angular velocity of the rotating system.

Although I_p and R are both increasing during the wind, their relative positions in the equation are such that the combined term within the brackets is substantially con-

stant. It therefore follows that T_i is essentially directly proportional to ω^2.

The ordinary clutch is not capable of compensating for the variation in inertial torque during the wind. This is particularly true as winding speeds are increased because of the marked effect the higher speeds have on increasing initial inertial torque. This accounts for the experience with prior machines that as higher operating speeds are attempted more frequent breakage of the web material is encountered.

FIG. 2 further illustrates the other torque factors which have been determined to be present in the winding of weak webs at high speeds. The line identified as "Friction Torque" illustrates the magnitude of the effect mandrel friction and windage have in tending to slow the mandrel and the web wound thereon. The winding system is held in equilibrium by the "Web Torque," which simply is that torque which is imposed on the rotating mandrel by tension in the web and which equals the algebraic sum of the clutch torque and the inertial torque, less the friction torque.

FIG. 3 illustrates graphically the more favorable winding conditions which can be practiced utilizing the present invention. It will be noted that in this example the tension is held substantially constant at approximately 8 lbs. from the beginning to the end of the wind. The inertial torque and the friction torque exhibit substantially the same magnitudes and behaviors as in the system illustrated in FIG. 2. In this instance, however, the clutch torque is programmed to produce a constant tension wind and it will be noted that this clutch torque profile is substantially different from the clutch torque profile of the prior machines represented by FIG. 2. It will also be noted that the web torque follows a smoothly increasing curve in the negative direction as would be expected in winding a web on a growing roll at constant tension.

Programmed centrifugal clutch

The web wind conditions illustrated graphically in FIG. 3 can be reproduced in accordance with this invention by means of a centrifugal releasing clutch having imposed thereon a programmed control which modifies the inherent torque imparting ability of the clutch in accordance with the progress of the wind. A preferred embodiment of this clutch is illustrated in FIG. 4 and is identified generally by reference numeral **22**. There is one such clutch **22** for each winding mandrel **11** and each clutch is carried by its mandrel preferably in a location between spiders **26** and **27** of the turret **12**. Spider **26** has securely clamped thereon a sleeve **28** within which mandrel **11** is free to turn in a bearing **29**. An extension of sleeve **28** has rotatably mounted thereon a drive wheel, or pulley, **31**. Pulley **31** is mounted on bearings **32** which enable the pulley to rotate freely on sleeve **28** and independently of mandrel **11**. Pulley **31** is equipped with a V-shaped channel **33** for engagement with drive belt **21** (see FIG. 1). One end of pulley **31** has a flange extension providing a clutch face **34** which constitutes a friction surface of the clutch.

Clutch face **34** of pulley **31** is engaged by a plurality of felt friction pads **36** disposed in circular array about the clutch face. Each friction pad **36** is carried in a holder **37** having a radial support arm **38** which is pivotally mounted by means of a pin **39** in a ring **41**. Ring **41** is secured to an elongated sleeve **42** which is keyed to mandrel **11** for rotation therewith. The spider-like assemblage of friction pad holders **37** is rotatable with the mandrel **11** and capable of transmitting torque forces to the mandrel **11** as a result of frictional engagement of pads **36** with rotating clutch face **34**. Friction pads **36** are held in engagement with clutch face **34** by suitable biasing means preferably in the form of helical springs **43** compressively disposed between pad holders **37** and a backup ring **44** carried for rotation with sleeve **42**, but axially slidable on sleeve **42**.

Referring to FIG. 6, it will be noted that the mounting of each friction pad holder **37** is such that the combined centroid of the holder **37** radial arm **38** and friction pad **36** is displaced longitudinally of the clutch assembly from the axis of mounting pin **39** so that centrifugal force acting on the pad holder **37**, radial arm **38** and pad **36** at the centroid during rotation of the mandrel **11** results in establishment of a force couple tending to rotate the pad holder **37** in clockwise direction about pivot pin **39** in opposition to the force of compression spring **43**. Thus, centrifugal force acting on each of the pad holders **37** tends to reduce the force with which the pads **36** are held against clutch face **34** as the rotational velocity of the mandrel increases. At very high speeds it is possible for the force couple acting on each pad holder **37** to completely overcome the force of its compression spring **43** and separate clutch pad **36** from clutch face **34** so that no torque will be transmitted across the face of the clutch. With this construction it is possible by careful design of the assemblage of clutch holders **37** to provide in each clutch **22** a speed responsive torque transmitting characteristic inversely proportional to the square of the angular velocity of a mandrel **11** so that the clutch transmits substantially less torque when traveling at high speed at the beginning of the web wind than when the mandrel slows down as the wind progresses. Preferably, the torque profile of the centrifugal portion of the clutch is designed to be comparable to but opposite to the profile of the inertial torque of the system as illustrated by the inertial torque curve in FIG. 2.

It should be evident from the earlier discussion of FIG. 2 that there are other torque conditions acting on the winding system which are not overcome by a centrifugal clutch designed to cancel the inertial torque of the system. There are, for example, the effects of friction torque and the requirement for increasing torque as the roll grows during winding. In accordance with this invention there is superimposed upon the centrifugally actuated clutch system a program control which modifies the operation of the clutch in accordance with the progress of the wind, i.e., length of web wound. The program control accounts for the other variable torque conditions to enable the clutch to impart to the mandrel the constantly changing torque required to wind the web at constant tension. This programmed modifying means includes a cylindrical cam actuating sleeve **47** concentrically disposed about mandrel sleeve **42** and having one end connected to clutch ring **44** by means of a bearing **48**. Sleeve **47** has cam surfaces **49** cut in the opposite end thereof fwhich are adapted to bear against rollers **51** carried on an operator adjustment ring **52**. Throughout most operating periods of the machine ring **52** is stationary with respect to trunnion spider **27**, but may be moved by the operator for making fine adjustments as is explained below.

As shown in FIGS. 4 and 7, cam sleeve **47** has an actuating arm **53** attached thereto and extending inwardly of the machine turret **12**. Movement of arm **53** imparts rotation to the cam sleeve **47** and this movement is translated into axial movement of sleeve **47** by virtue of cam surface **49** riding on rollers **51**. Axial movement of sleeve **47**, in turn, imparts axial movement to clutch ring **44** to change the compression of clutch springs **43** to vary the effectiveness of these springs in biasing friction pads **36** into engagement with clutch face **34**. When viewed from the right-hand end of mandrel **11** as shown in FIG. 4, clockwise movement of sleeve **47** increases the compression of springs **43** and counter-clockwise rotation of sleeve **47** decreases the compression of springs **43**.

Movement of actuating sleeve **47** is effected by cam means responsive to the progress of a web wind. A preferred form of cam means for this purpose is illustrated in FIG. 9 and takes the form of a large circular cam **56** which is supported for rotation about the axis of turret **12** by means of a series of wheels **55**. The outer surface of cam **56** is adapted to be engaged by follower rollers **58**

carried at the ends of the several actuating arms **53** for the cam sleeves **47**. Cam **56** has a program surface segment **59** adapted to effect movement of one actuating arm **53** in a controlled manner for the clutch **22** of the mandrel upon which a web is being wound. Cam **56** also has a high rise dwell segment **60** ahead of program segment **59** which is adapted to effect overload of a clutch **22** as the mandrel for that cam is moving into winding position to insure the mandrel being brought up to initial winding velocity.

Relative movement of cam **56** with respect to turret **12** is effected by means of a drive system which synchronizes movement of cam **56** with the amount of web material wound on the mandrel. While other drive means, such as a flexible shaft, can be used for this purpose, the drive illustrated comprises a gear **61** affixed to cam **56** and a pinion **62** carried on the shaft of a stepping motor **63** which is affixed in any suitable manner to the turret **12**. Movement of cam **56** is in the direction opposite to the indexing motion of turret **12** in bringing successive mandrels **11** into winding position. When observed from the end of the machine during operation, cam **56** will appear to oscillate while maintaining the same general relationship with a fixed object on the machine.

Stepping motor **63** is driven at a rate which corresponds to the operating speed of the machine and, consequently drives cam **56** with a rotational movement corresponding to the progress of a web wind. Motor **63** is preferably energized from a pulsing system which may take the form of a switch **64** located in the vicinity of bed roll **14** and actuated by a cam **66** rotating with bed roll **14** (see FIG. 1). Electrical leads **67** from switch **64** are connected by means of a suitable slip ring assembly (not shown) to corresponding leads **67** on the stepping motor **63**.

The clutch mechanism of FIG. 4 is preferably provided with an operator adjustment permitting displacement of the torque profile of the clutch **22** to higher or lower limits to enable the operator to select a more tightly wound or a more loosely wound roll in order to maintain a predetermined roll size when winding webs of different bulk. As shown in FIG. 8, this adjustment is effected by rotating adjustment ring **52** by means of a hand screw **71** passing through the ring mounting **72** and engaging a notched-out region **73** of ring **52**. Sleeve **52** is maintained in contact with hand screw **71** by means of a backing spring **74** at the opposite side of the ring. Rotation of ring **52** relative to adjustment cam sleeve **47** has the effect of axially shifting sleeve **47** and changing the compression in clutch springs **43**.

Operation of programmed centrifugal clutch

When the machine is in operation, the turret **12** will index one of the mandrels **11** into winding position to receive the leading edge of a web being fed over bed roll **14**. As the mandrel approaches winding position, the groove **33** of the clutch pulley **31** engages drive belt **21**. Belt **21** is moving at a velocity which rotates clutch pulley **31** at an angular velocity which matches the surface velocity of the mandrel **11** to the velocity of the web leaving bed roll **14**. During this pre-wind period it is highly desirable that there be no slippage in the clutch **22** so that the mandrel **11** positively assumes the desired angular velocity. This condition is assured by virtue of the clutch compression springs **43** being subjected to higher than winding compression by virtue of the follower roller **58** of the actuating arm **53** of the clutch being in engagement with the high rise dwell segment **60** of the program cam **56**. The cam **56** at this location is effective to rotate adjustment cam cylinder **47** to its maximum clockwise position as viewed in FIG. 9 and to thereby move clutch ring **44** to a leftmost position as viewed in FIG. 4. The compression of clutch springs **43** at this point is such as to more than overcome the centrifugal force couple acting on clutch pad arms **37**, notwithstanding the high rotational velocity of the clutch and the mandrel at this point.

As the mandrel **11** reaches its winding position and web **15** is transferred to the mandrel to start the wind, cam follower **58** on clutch actuating arm **53** moves into the program segment **59** of cam **56**, allowing cam cylinder **47** to undergo counter-clockwise movement to release some of the compression in clutch springs **43**. This allows the centrifugal force couple acting on clutch pad holders **37** to tend to rotate the holders about their pivot pins **39** and relieve the frictional engagement between the clutch pads and the clutch face **34**. As can be observed from the clutch torque curve in FIG. 3, the torque transferred to the mandrel through clutch **22** is quite low at the beginning of the wind. At this point the inertial torque of the clutch and mandrel substantially assist in winding the web **15** onto the mandrel with very little, if any, additional torque being required.

As the wind progresses and the roll of web material on the mandrel increases in size, the inertial torque decreases rapidly because of slowing of the mandrel velocity. During this period additional torque is applied to the clutch **22** because the centrifugal force couples acting on pad holders **37** diminish and the friction pads **36** are pressed into tighter engagement with the clutch face **34** by compression springs **43**.

Simultaneously, as the wind progresses and the roll diameter increases, additional torque must be transmitted to the mandrel **11** by the clutch **22** to compensate for the growing moment arm through which mandrel torque is applied to the web **15**. The torque transmitting ability of the clutch **22** is increased in a programmed manner by virtue of the clutch actuating arm **53** following the progressively increasing radius of program segment **59** of cam **56**. The torque transmitting, or imparting, ability of clutch **22** is thus caused to follow the general profile indicated by the clutch torque curve in FIG. 3 by the combination of the centrifugal force acting on friction pad holders **37** and the programmed change of compression of clutch biasing springs **43** under control of program cam **56**.

At the end of the wind web **15** is severed by the knife **19** in bed roll **14** and the mandrel **11** containing the completed roll is indexed by turret **12** out of winding position as the succeeding mandrel is brought into position. Clutch **22** of the mandrel containing the wound roll is thus moved out of engagement with drive belt **21** and this mandrel is allowed to stop so that the roll wound thereon can be removed.

During the winding operations on the several mandrels program cam **56** is advanced with respect to turret **12** in properly timed relationship to the progress of the wind by means of stepping motor **63** which is energized from switch **64** which is actuated by cam **66** rotating with bed roll **14**.

Programmed fan drag clutch

FIG. 11 illustrates another emobdiment of this invention in which modified means are employed to reduce the torque transmitting ability of a winding clutch in proportion to the square of the velocity of the mandrel. In this clutch, identified generally by the reference numeral **80**, a number of components are employed which are the same as those employed in clutch **22** of FIG. 4 and like reference numerals will be used to identify common parts.

Clutch **80** has a pulley **31** which is driven for rotation independently of mandrel **11** and which has a clutch face **34**. Keyed to mandrel **11** for rotation therewith is an elongated sleeve **42**. Sleeve **42** carries for rotation therewith a slidably mounted clutch ring **81** which has imbedded in one face thereof a circular array of friction pads **36** positioned to engage clutch face **34**.

Friction pads **36** are urged against clutch face **34** by an array of compression springs **82** bearing on the back face of clutch ring **81** and carried in recesses in the face of a hub **83**. Hub **83** is mounted for rotation with sleeve **42** but is movable axially thereon for the purpose of varying the compression of springs **82**. Like the programmed

centrifugal clutch described above clutch **80** has a cylindrical cam actuating sleeve **47**, the axial motion of which shifts hub **83** to vary the torque transferring ability of the clutch as the wind progresses.

Clutch **80** also has means which vary the torque imparting ability of the clutch in inverse proportion to the square of the mandrel velocity. This function is performed by fan means comprising a plurality of blades **84** mounted on hub **83** which rotates with sleeve **42** at the same angular velocity as mandrel **11**. Blades **84** rotating with mandrel **11** encounter resistance from the surrounding air of a magnitude which is directly proportional to the square of the velocity with which the fan is turned. This characteristic is inherent in fan means. The fan means is thus capable of "absorbing" torque in the same proportion as inertial torque is generated by deceleration of the rotating system and, in effect, prevents the clutch from transferring to mandrel **11** the equivalent of the inertial torque.

Operation of fan drag clutch **80** in conjunction with program cam **56** and the remainder of the winder is identical to the operation of centrifugal clutch **22** described above.

One of the principal advantages of varying the torque imparting ability of the winder clutch by speed responsive means such as the fan blades **84** of clutch **80** and the centrifugally actuated pad holders **37** of clutch **22** is that the clutch automatically compensates for different winding speeds. FIG. 12 illustrates by means of a family of curves the different torque profiles required to be imparted to the winding mandrel at different web speeds in order to wind a web at constant tension. The higher the winding speed the less clutch torque must be imparted to the mandrel **11** in order to keep the tension in the wound web at the desired level. This requirement is the result of increased inertial torque effects present in the system at higher operating speeds. Both the centrifugal clutch **22** and the fan drag clutch **80** exhibit velocity squared characteristics closely corresponding to variations in inertial torque with changing winding speed. Both clutches, therefore, automatically compensate for changes in winder speed.

It will be noted from FIG. 12 that at winding speeds of 2,000 feet per minute and above a negative torque is actually required to be imparted to the winding mandrel at the beginning of the wind. It can be readily appreciated that the fan blades **84** of the fan drag clutch **80** can be designed to "absorb" more torque than is actually transferred to friction pads **36** and, in effect, apply negative torque to the winding mandrel at the beginning of the wind. The fan drag clutch **80** is thus capable of operating throughout the speed range illustrated in FIG. 12. Centrifugal clutch **22** has the limitation of being unable to impart negative torque to the winding mandrel **11** and therefore cannot operate as effectively at speeds in excess of those at which the negative torque requirements at the beginning of the wind are in excess of that negative torque which is provided by the friction and windage of the system. For the examples illustrated in FIG. 12 this upper speed limit for the centrifugal clutch **22** is approximately 2,000 feet per minute.

From the foregoing it should be apparent that this invention provides novel means for improving the performance of high speed winding machines. The ability of clutch systems constructed in accordance with this invention to program clutch torque applied to winding mandrels and thereby maintain a uniform tension in the web being wound is of particular significance in winding weak webs, such as perforated toilet tissue, which may be caused to break by even slight variations in the winding tensions.

Moreover, it should be apparent that this invention is useful in winding applications wherein a tension profile during the wind is desired which is something other than constant tension. For example, in winding high gloss films it is desirable to wind the inner layers of the roll more tightly than the outer layers in order to prevent slippage of the inner layers during the latter part of the wind. For such applications, it is possible to alter the shape, or profile, of the program segment **59** of cam **56** so as to impart to the clutch the desired torque transfer profile while still essentially canceling the inertial torque by means of the speed responsive attributes of the system.

While the invention has been described with reference to particular embodiments thereof it is understood that changes and modifications may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. In web winding apparatus, a rotatable mandrel on which the web is to be wound, drive means, a clutch for transmitting torque from said drive means to said mandrel, means responsive to the velocity of said mandrel and acting on said clutch to reduce the torque transmitted to the mandrel as a function of the square of the velocity of the mandrel, and program means responsive to the progress of a wind on said mandrel and acting on said clutch for progressively controlling the torque transmitting ability of the clutch over a range of values during the web wind.

2. In a web winding apparatus, a rotatable mandrel on which the web is to be wound, drive means, a clutch driven by said drive means and adapted to impart torque to said mandrel, means responsive to the velocity of said mandrel and acting on said clutch to reduce the torque imparted to the mandrel in proportion to the inertial torque in the winding apparatus, and program means responsive to the progress of a wind on said mandrel and acting on said clutch to progressively control the torque imparting ability of the clutch over a range of values during the web wind.

3. In web winding apparatus, a rotatable mandrel on which the web is to be wound, drive means, a clutch for transmitting torque from said drive means to said mandrel, said clutch being responsive to the velocity of said mandrel and exhibiting the characteristic of reducing the torque transmittable by the clutch with increasing mandrel velocity, and program means responsive to the progress of a wind on said mandrel for modifying the characteristics of said clutch to progressively control the torque transmitting ability of the clutch over a range of values during the web wind.

4. In web winding apparatus, a rotatable mandrel on which the web is to be wound, drive means a clutch for transmitting torque from said drive means to said mandrel, said clutch including at least two friction members and means biasing said members into frictional engagement, centrifugal means responsive to the velocity of said mandrel for opposing said biasing means and enabling said clutch to exhibit the characteristic of reducing the torque transmittable by the clutch in proportion to the square of the mandrel velocity, and program means responsive to the progress of a web wind for progressively increasing the effectiveness of said biasing means to modify the characteristics of said clutch during a wind, said program means being effective to control the torque transmitting ability of the clutch over a range of values during the wind.

5. In web winding apparatus, a rotatable mandrel on which the web is to be wound, constant velocity drive means, a clutch for imparting torque to said mandrel when the clutch is driven by said drive means, fan means rotating with said mandrel and acting on said clutch to reduce the torque imparted to the mandrel in proportion to the square of the velocity of the mandrel, and program means responsive to the progress of a wind on said mandrel and acting on said clutch for progressively controlling the torque imparting ability of the clutch during the web wind.

6. In apparatus for winding webs at constant velocity and with a predetermined tension profile, a rotatable

mandrel on which the web is wound, a turret supporting said mandrel and adapted to move the mandrel into winding position, constant speed drive means, clutch means carried by said mandrel and capable of imparting a varying torque to said mandrel when the cltuch is driven by said drive means, and said clutch means exhibiting the ability to impart a reduced torque in proportion to the square of the velocity of the mandrel, means for adjusting the torque imparting ability of said clutch means, cam means, movable with respect to said turret for actuating said adjusting means, and means responsive to the progress of a web wind for actuating said cam means

7. In web winding apparatus having a plurality of rotatably mounted mandrels, turret means supporting said mandrels and adapted to successively index said mandrels into winding position, drive means, means carried by each of said mandrels and adapted to be driven by said drive means when its mandrel is in winding position, clutch means carried by each of said mandrels capable of imparting varying torque to the mandrels from said driven means, and means for varying the torque imparting ability of the clutch means during a web wind, said varying means being adapted to maintain the torque imparting ability of the clutch at a high level as the mandrel approaches winding position to insure rotation of the mandrel at a velocity comparable to the velocity of said drive means, to reduce the torque imparting ability of the clutch to a lower level as a web is transferred to the mandrel for winding, and to subsequently progressively increase the torque imparting ability of the clutch during a web wind.

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