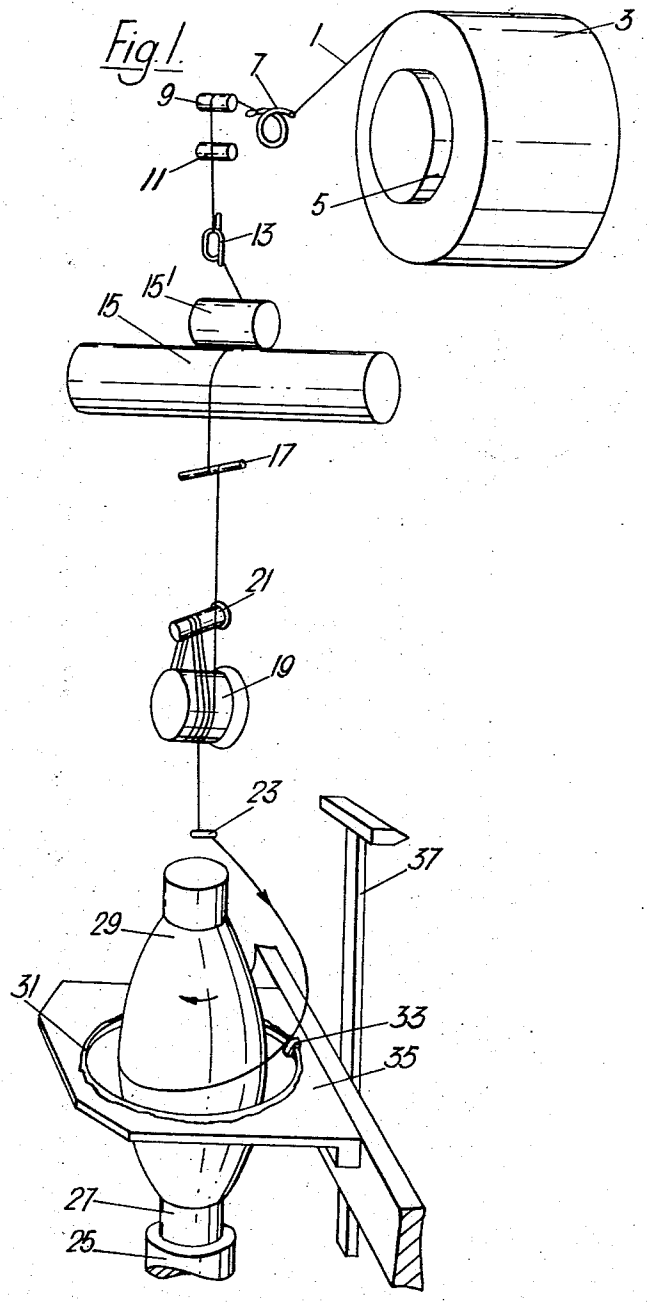
Dec. 19, 1967 H. E. CURTIS ETAL 3,358,433

COLLECTION OF SYNTHETIC POLYMERIC YARNS OR FILAMENTS

Filed Sept. 26 1966 4 Sheets-Sheet 1

Fig. 1.



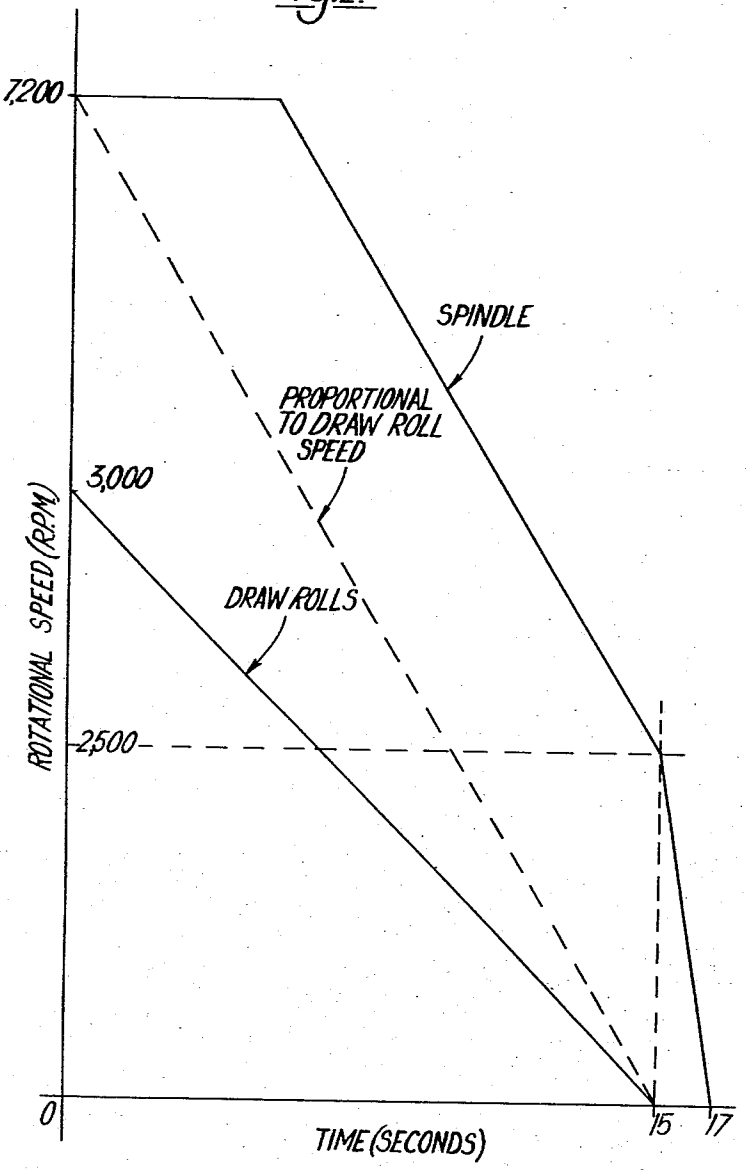
Inventors
HAROLD EDWARD CURTIS
BRYAN RINGSLEY JOHNSON
JOHN PERCIVAL RUSSELL
By
Cushman, Darby & Cushman
Attorneys

Dec. 19, 1967 H. E. CURTIS ETAL 3,358,433

COLLECTION OF SYNTHETIC POLYMERIC YARNS OR FILAMENTS

Filed Sept. 26 1966 4 Sheets-Sheet 2

Fig. 2.



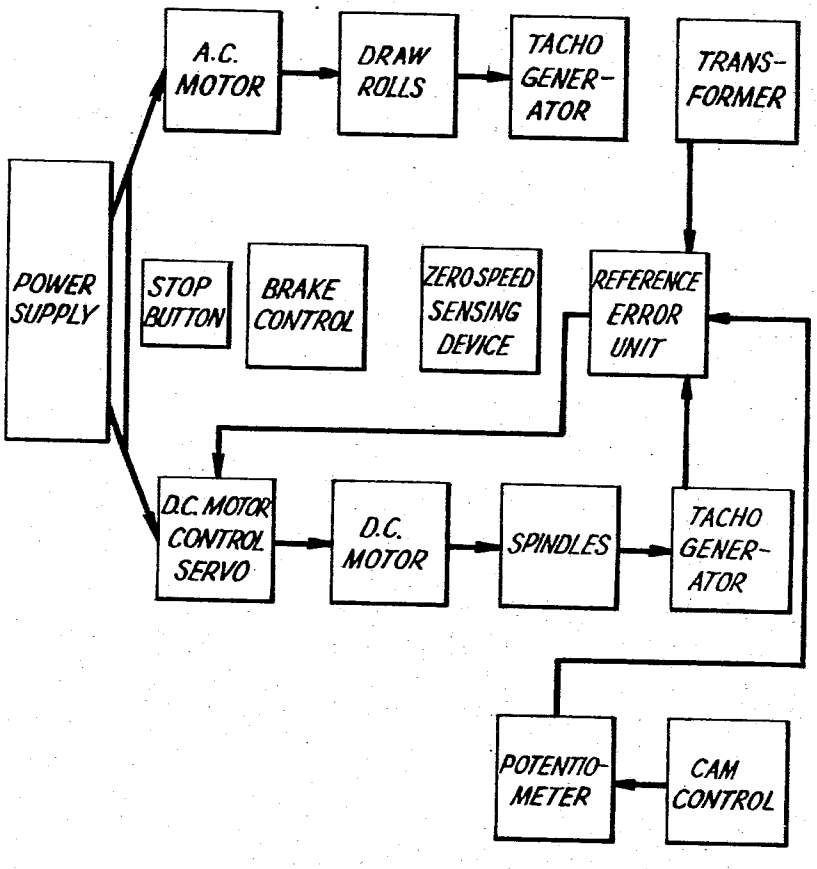
Inventors
HAROLD EDWARD CURTIS
BRYAN KINGSLEY JOHNSON
JOHN PERCIVAL RUSSELL
By
Cushman, Darby & Cushman
Attorneys

Dec. 19, 1967 H. E. CURTIS ETAL 3,358,433

COLLECTION OF SYNTHETIC POLYMERIC YARNS OR FILAMENTS

Filed Sept. 26 1966 4 Sheets-Sheet 3

Fig. 3.



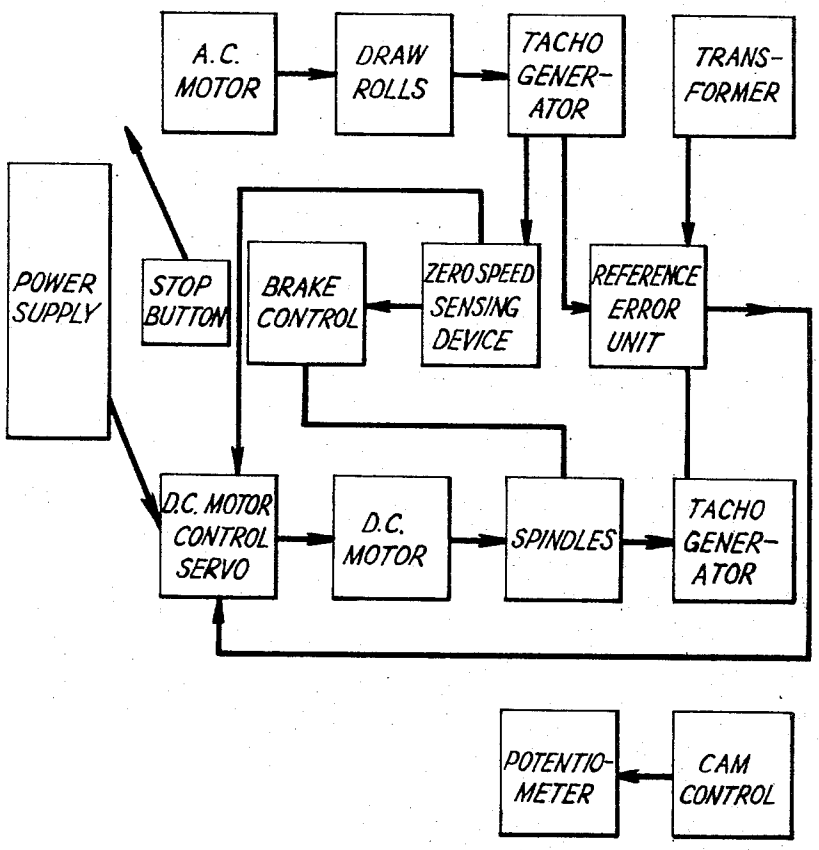
Inventors
HAROLD EDWARD CURTIS
BRYAN KINGSLEY JOHNSON
JOHN PERCIVAL RUSSELL
By
Cushman, Darby & Cushman
Attorneys

Dec. 19, 1967 H. E. CURTIS ETAL 3,358,433

COLLECTION OF SYNTHETIC POLYMERIC YARNS OR FILAMENTS

Filed Sept. 26 1966 4 Sheets-Sheet 4

Fig. 4.



Inventors
HAROLD EDWARD CURTIS
BRYAN ZINGSLEY JOHNSON
JOHN PERCIVAL RUSSELL
By
Cushman, Darby & Cushman
Attorneys

United States Patent Office

3,358,433

Patented Dec. 19, 1967

3,358,433

COLLECTION OF SYNTHETIC POLYMERIC YARNS OR FILAMENTS

Harold E. Curtis, Cwmbran, and Bryan Kingsley Johnson and John P. Russell, Abergavenny, England, assignors to Imperial Chemical Industries Limited, London, England, a corporation of Great Britain

Filed Sept. 26, 1966, Ser. No. 581,864
Claims priority, application Great Britain, Oct. 1, 1965, 41,758/65
6 Claims. (Cl. 57—93)

This invention relates to a method and apparatus for winding yarn packages especially of synthetic polymeric filaments or yarns, and is particularly concerned with the collection of such filaments in the form of packages on bobbins mounted on rotating spindles, in conventional drawing apparatus, or other forms of over-end winding apparatus of the kind in which the filaments are fed to the spindles via rotating processing rolls, and the completed packages are brought to rest before being doffed, and the empty bobbins are brought from rest up to an initial operable rotational speed after the filaments have been secured thereto for rotation therewith.

The term "apparatus of the kind specified," will be used hereinafter to refer to such apparatus.

Over-end winding apparatus may, for example, have a ring-and traveller yarn guide around each spindle, or comprise cap-spinning apparatus; but for convenience in describing the invention in this specification it will be assumed that the apparatus has a ring-and-traveller yarn guide, although it must be understood that the present invention applies also to other forms of over-end winding apparatus. The packages produced by such apparatus will usually be tapered in form.

Further, for convenience in this specification, the roll or co-operating rolls, which engage the running filament immediately before it is collected on the package, will be referred to hereinafter and in the claims as the "draw rolls," although as indicated above, the present invention is applicable to various kinds of apparatus other than drawing apparatus. By "drawing" we mean that a filament of synthetic polymeric material is stretched to cause the molecules to orientate themselves along the filament axis, thus increasing the tenacity of the filament.

The filament may pass between the nip of two co-operating "draw" rolls, or be wrapped around a single roll, or around a pair of co-operating rolls comprising a rotating roll and separator roll, which latter may be rotating or stationary.

The winding apparatus may include programming means arranged to vary the speed of the spindle throughout the major part of the winding of each package, for some particular purpose; and the present invention is particularly, but not exclusively, concerned with such over-end winding apparatus in which it is possible so to vary the value of the spindle speed according to a desired programme.

In over-end winding apparatus, it may be shown that the spindle speed is equal in magnitude to the traveller speed plus the winding-on speed of the filament, this latter term being the fraction of spindle speed corresponding to the winding-on of the filament, and being equal in magnitude to the spindle speed if the traveller is stationary.

Thus, it is possible to control some feature of the winding operation which is related to winding-on speed and traveller speed throughout the production of a package, in order to obtain some desired object, by employing a suitable spindle speed programme.

In any such spindle speed programme, the traveller speed should not, under known conditions, be allowed to

exceed 7000 r.p.m., except transiently, otherwise the yarn guide device will be subjected to excessive stresses, and unacceptable wear and breakage will ensue.

Primarily, though, the spindle speed may be controlled to control the balloon tension of the filament, and it may be shown that the balloon tension of the filament, and hence the winding-on tension, is proportional to the square of the traveller speed and is inversely proportional to the instantaneous value of the package diameter.

Thus, by appropriate changes in the spindle speed throughout the production of a package, the yarn balloon tension may be maintained at a constant value. In this case, the traveller of a ring-and-traveller yarn guide may be considered to be primarily a wind-on guide, the speed of which controls the yarn winding-on tension, and not a means of inserting twist into the yarn.

It is often desirable that the balloon tension be maintained at a substantially constant value throughout the winding operation, because fluctuations in this value may cause streaks to occur in the fabric into which synthetic polymeric filament yarn is eventually made-up, stress differences between different parts of the package being the cause of barre and being a cause of warp stripes in woven fabrics.

Further it is desired that a stable package be produced; and thus it is essential that the filament be tensioned to an extent above a certain minimum value so that a stable balloon be maintained, and the manner of the lay of the filament on the package be "predicted," and the filaments arranged to be securely laid on the package and not tending to slough off it.

Thus, the rotating traveller is used to tension the running filament to the requisite amount in order that a stable balloon may be obtained throughout the winding operation, the balloon being tensioned to an amount of at least 0.1 gram per denier in the case of a polyamide filament, and the spindle speed is so programmed that the traveller speed is held within a predetermined narrow range of values.

It is particularly desirable that this condition should be maintained during the start-up and slow-down periods in the formation of each package, because, due to the reasons given above, such a condition will reduce the propensity of the filament to break during these periods (filament breakages being more likely to occur at these periods in the package winding cycle, than intermediate therebetween).

The present invention is concerned with obtaining such a winding condition while the winding machine is slowing down, by the provision of positive programming means arranged to control the spindle speed during this period. During this period also, loops tend to be formed on the package, if filament breakages are avoided, and the spindle speed programme during this period is therefore arranged to be such that both kinds of irregularities in the winding operation are reduced.

Slow-down breakages occur when the spindle rotational speed is reduced at a faster rate than is desired in relation to a given draw roll deceleration, with consequent over-feeding of the filament from the draw-rolls to the spindle causing an uncontrollable balloon to be produced. Thus, the filament may eventually lick back onto the draw rolls, or become entangled and snagged either with itself or on parts of the winding apparatus, and so break.

However, if the spindles are allowed to run-on by an excessive amount, or the draw rolls are braked too quickly, then the twist insertion rate in the balloon rises, and this twist runs back to the draw rolls, and a so-called "slow-down loop" will occur. Increase in the twist insertion rate occurs because, in the dynamic state, the form of the balloon will remain substantially constant. Thus, if the filament delivery speed, i.e., draw roll speed, is re-

duced sharply, the winding-on speed must reduce in proportion. However, if the spindle speed maintains the same value, the traveller must accelerate to compensate for the reduced winding-on speed, until when no filament is being delivered, then none of the filament is wound onto the package and the balloon will speed up until its rotationed speed is equal to that of the spindle. This increase in traveller speed and reduced winding-on speed accounts for the increase in the twist insertion rate.

The increased twist runs back up the filament and may cause a wrap of the filament to slip off the draw rolls, when these comprise a co-operating draw roll and separator roll. The sudden concomitant increase in the amount of filament in the balloon will cause a complete yarn loop to be wound onto the package.

It will be appreciated that it is relevant to such loop formation whether "S" or "Z" twist is being inserted into the filament, because, in a given form of winding arrangement, the insertion of one direction of twist will tend to keep the wraps on the draw rolls, while the insertion of the other direction will tend to cause the wraps to roll off the draw rolls.

Single filament loops may, however, be caused in the threadline even if complete yarn loops are not produced; and these single filament loops are equally prejudicial to the usage of the yarn.

The existence of any slow-down breakages and loops will result in the packages sold being slightly below standard weight (because the portion of the filament with loops will have to be stripped from the package during inspection), if as is usual it is intended that the portion of the filament processed during the slow-down operation of the winding apparatus should form part of the package. If slow-down breakages and loops can be eliminated, it will obviate the need for packages to be superficially inspected, and so cause a reduction in operation costs.

With respect to the production of standard weight processed packages, it will be appreciated that winding apparatus having a programmed winding procedure, and in particular a programmed slow-down procedure, will be less likely to suffer from between doff variations in the winding operation, and hence there is less likelihood of uncontrollable variations in package weight occurring, compared to winding apparatus which is not controlled in such a positive manner.

It is of importance not to produce packages of below standard weight due to unintentional breakages occurring, or due to the formation of loops, because of their possible unsuitability for use in subsequent manufacturing processes. Further, there will be a high wastage rate if the filament wound thereon is to be used in specified discrete amounts, because the amount of the filament remaining on the supply package will be considerably more than was intended after, say, processed packages of a specified weight have been wound therefrom.

This wastage of the filament will be particularly important if heavy denier yarns are being processed on the machine, which yarns usually are desired to have as high a throughput rate as possible and have a relatively shorter package winding cycle.

The presence of loops in the package will also cause package instability at their locations and this will cause a transient relatively large reduction in the take-off tension of the filament at this point when unwinding the filament from the package. The package will, therefore, be unsuitable for use on a creel where the filament of one package is connected to the filament of an adjacent package.

Hence, it will be appreciated that, it is important to be able to predict precisely the slow-down procedure for the winding apparatus, and the spindle speed programme should be such that there is avoidance both of slow-down breakages due to the spindle speed decaying too quickly, and of slow-down loops due to the spindle running on more than was intended. It may be possible according to this invention to arrange the slow-down winding conditions such that both these faults can be eliminated; but in any event a compromise solution can be adopted so that the optimum winding conditions for minimum slow-down breakage rate and loop formation rate are obtained.

If such optimum conditions are attempted to be employed in winding apparatus not having positive programming means, it is found that the manner of operation of the apparatus requires constant observation in order that the critical conditions be maintained, and the controlling elements of the apparatus require constant trimming to preserve the desired manner of operation, particularly if the slow-down period is initiated when the package rotational speed is relatively high and the package being wound is relatively large.

For example, the extent of the restraint applied by braking means for the spindles will vary, if the means is required habitually to apply a relatively heavy braking restraint, and this means will require constant re-adjustment. Meanwhile the manner of operation of the machine will have varied, with a consequent rise in the filament loop rate. Further, if heavy breaking is required, this implies an expensive and complicated braking system which will means additional maintenance for the machine.

In one conventional form of winding apparatus of the kind specified, the spindles, or say, a group of four spindles are driven by a single tape, each spindle being in frictional contact with the tape.

In addition, with this type of winding apparatus when the spindles slow down, because of their relatively high inertia, each spindle having a yarn package for rotation therewith, there is slippage between the spindles and the tape. Thus, the spindles will tend to decelerate at a slower rate than the draw rolls, even if the speed of the latter is allowed to decay freely, because of the relatively high inertia of the spindles, even though greater frictional force may be acting upon the spindles.

The substantially uncontrollable manner in which the spindles are brought to rest implies that the winding operation will vary between different spindles driven by the same tape, and between the same spindle in different package winding cycles.

In addition it may occur that in a group of packages driven by a single tape, certain of them may have slow-down breakages, and others have slow-down loops. Hence, the adjustment of the apparatus in order to eliminate the presence of the one effect, may only cause the enhancement of the other; and the adoption of the optimum conditions will still result in the formation of imperfect packages by the apparatus.

It is an object of the present invention to provide over-end winding apparatus which will tend to cause a reduction in the number of slow-down filament breakages and in the formation of slow-down loops, by the provision of positive programming means for the spindle drive means of the winding apparatus, to be operative during this period.

It is a further object of the present invention to provide over-end winding apparatus having such programming means for the slow-down period which is comparatively simple in form, reliable in operation, and will not require frequent attention and maintenance.

It is another object of the present invention to provide over-end winding apparatus for producing, consistently and reliably, satisfactory standard-weight tapered packages, the portion of the filament processed while the apparatus is slowing down being included in the package in its complete form.

According to one aspect of the present invention, over-end winding apparatus of the kind specified has a motor adapted to drive the spindles separately from the draw rolls, the draw rolls themselves being driven by another motor, e.g., that of the main drive means of the machine, characterised in that programming means is provided to control the winding operation of the apparatus in a posi-

tive manner at least during the slow-down period of the full package winding cycle, said programming means including a servo device for controlling the spindle drive motor, tacho-generators for the draw rolls and spindles respectively to monitor their speeds and produce electrical signals related thereto and a reference error unit adapted to compare said electrical signals during said slow-down period and to feed a resultant electrical signal therefrom to said servo device.

The spindle drive means may comprise a D.C. motor, the operation of such a motor being relatively easy to programme; and the draw roll drive means, comprising the main drive means of the machine, may be an A.C. induction motor.

The manner of operation of the D.C. motor is controlled by the servo device, which may comprise a 3-phase magnetic amplifier the input of which is controlled by a pre-amplifier, the current from a rectifier positioned across one phase of the electrical supply to the device comprising the shunt field excitation current for the motor.

The programming means includes a first tacho-generator arranged to monitor the spindle speed, a second tacho-generator arranged to monitor the draw roll speed during the slow-down period, and a reference error unit arranged to compare the signals produced by both tacho-generators and to feed a signal to the spindle drive means servo device, this latter signal being such that the spindle speed is in a predetermined relationship to the draw roll speed during the first part of the slow-down period, i.e., while the draw rolls are rotating.

However, in order to ensure that the traveller speed is above the predetermined minimum requisite value to maintain a stable balloon when the draw rolls have been brought to rest, a signal of magnitude sufficient to maintain the spindle speed at the desired corresponding value when the draw rolls have stopped is arranged by the reference error unit to be compounded with the signal which would maintain strict proportionality between the spindle speed and the draw roll speed, and the composite signal is fed to the spindle drive means servo device.

In order to prevent the formation of slow-down loops, the second tacho-generator, i.e., that which is coupled to the draw roll drive shaft, is connected to a zero-speed sensing device, which devices is operably connected to brake means for the spindles and actuates this brake means when it has sensed that the draw rolls have stopped, so that the spindles are stopped by the brake means as soon as possible after the draw rolls have been brought to rest.

In practice, the programming means is arranged to ensure that the spindles are driven by their associated D.C. motor against light braking restraint throughout the first part of the slow-down period, so that this motor does not tend to "hunt."

The programming means may include means capable of adjustment initially during the setting up of the winding apparatus, which means will ensure that the transference of the winding apparatus from its normal procedure to its slow-down procedure occurs in a smooth manner without an abrupt change in either the spindle speed or the traveller speed.

In one embodiment of such over-end winding apparatus the programming means is capable also of controlling some aspect of the winding operation throughout the major part of each package winding cycle. In one such case, the spindle speed is programmed so that an abrupt increase in the rotational speed of the spindle occurs at each of a series of predetermined times in the winding cycle of a package during which the mean spindle speed is generally reduced. Such abrupt increases in spindle speed are provided at the times of winding when, due to the conditions of winding a region of patterning in the lay of the filaments can otherwise be expected to occur.

Hence, the arrangement may be such that the programming means has a modified form during the slow-down period of a package winding cycle, compared with that employed during the major part of the package winding cycle.

In one such form, the programming means when controlling the spindle speed throughout the major part of each package winding cycle includes a potentiometer, the position of the slider of this potentiometer being controlled by a cam embodying the desired winding programme for the normally operating part of each package winding cycle, and the output signal from this part of the programming means is fed to the reference error unit.

Thus, the output of the potentiometer comprises a variable reference signal, which is compared by the reference error unit with the output of the first tacho-generator, i.e. that operably coupled to the spindles and arranged to monitor their speed, and the reference error unit is arranged to produce an error signal which is fed to the spindle drive means servo device to adjust the setting thereof.

According to another aspect, therefore, the present invention resides in a method of winding a package by over-end winding apparatus of the kind specified, which method comprises programming at least the slow-down period of the package winding cycle comprising a start-up period, a main winding period and a slow-down period, said programming of the slow-down period in said package winding cycle being such that the spindle speed is positively controlled in a predetermined relationship to the draw roll speed during the first part of said period until the draw rolls become stationary, whereafter the spindle is brought to rest.

The above-mentioned predetermined relationship may comprise two components, the first component being the maintenance of strict proportionality between the spindle speed and the draw roll speed while the latter is finite, and compounded therewith a component which alone would maintain the spindle speed at a constant value of a magnitude sufficient to sustain a stable balloon with the draw rolls stopped.

When the draw rolls have stopped, the spindle is arranged to be brought to rest as soon as is practical thereafter.

A light braking restraint may be arranged to be applied to the spindle during the first part of the slow down period, and the spindle drive means is controlled so as to drive the spindle against this light braking restraint, but such that the above-mentioned predetermined relationship is obtained. By this means, the spindle speed is prevented from "hunting" about its requisite value.

A specific embodiment of the present invention will now be described by way of example, but not limitation thereof, and with reference to the accompanying drawings, in which:

FIGURE 1 is a sketch of the various instrumentalities of a conventional draw-twist machine;

FIGURE 2 shows graphically a desirable slow-down programme according to the invention;

FIGURE 3 is a block diagram of a means for programming the main portion of the winding cycle of the apparatus of FIGURE 1; and

FIGURE 4 is a block diagram of said means when modified to programme the slow-down portion of the winding cycle, according to the invention.

In conventional draw-twisting apparatus for synthetic polymeric filaments, such as polyamide, polyester, or polyolefin filaments, there are included two or more pairs or sets of co-operating rolls, each pair of rolls being arranged to impart a different speed to the filament, causing the filament to be drawn between two adjacent pairs of rolls (and, optionally to relax between another two adjacent pairs of rolls).

Snubbing devices, which impose a substantial restraint on the running filament, may be included in the apparatus, so that there may be a single drawing zone or several such zones, and possibly also regions in which the yarn may

relax or be subjected to some other treatment process. The first pair of rolls which engage the yarn are feed rolls for the apparatus, and between these and the final pair of rolls, which are positioned immediately before the winding apparatus, and which are herein referred to as "draw rolls," the filament is stretched to many times its original length.

Thus, as shown in FIGURE 1 a polyamide filament 1 is withdrawn from a cheese 3 mounted on a container 5, and passes through yarn guide means 7, 9, 11, 13 to a pair of co-operating nip rolls 15, 15¹. From these nip rolls, which serve as positive feed rolls, the filament is wrapped around an inclined snubbing pin 17, which causes a considerable physical restraint to be imposed on the filament resulting in the filament "necking" and being stretched to, say, five times its original length. The filament then passes around draw roll 19 with its inclined separator roll 21, which rolls, which forward the filament to a balloon guide 23 and thence to winding apparatus.

The winding apparatus comprises a vertically extending spindle 25 on which a tube 27 for the yarn package 29 is rotatably mounted, and around which spindle yarn guide means is disposed for causing the filament to be laid on the package. The yarn guide means is in the form of a conventional ring 31 and traveller 33 device mounted on a ring rail 35 this ring rail being reciprocated along the spindle axis by a known form of builder mechanism, including a striker plate 37 secured to the ring rail for reciprocation therewith. At each end of each reciprocation stroke the plate is arranged to operate a microswitch (not shown) and so cause reversal in the direction of movement of the ring rail. The positions of the microswitches are controlled respectively by two cams rotatably mounted on a shaft driven at a constant speed.

The main drive means for the drawtwist machine comprises an A.C. induction motor coupled to each of the feed rolls and the draw rolls of the machine, but not to the spindles on which the packages are being formed, the spindles arranged to be driven by a separate D.C. motor.

Thus, the drive means of the draw-twist machine is in two parts, and hence both the spindles and the draw rolls can be allowed to accelerate and decelerate independently of each other during the start-up and slow-down periods of each package winding cycle.

In order that filament breakages shall be avoided during the start-up period of each package winding cycle, an electrical timer is included in the winding apparatus, this timer being arranged so that the draw rolls (and the feed rolls) are not driveably connected to the A.C. motor until after the spindles have been driveably connected to the D.C. motor. The setting of the timer is adjustable manually.

The criteria upon which the optimum value for the delay period in starting the A.C. motor after the D.C. motor is determined are set out below.

It is essential that a stable balloon be maintained as soon as the draw rolls have started to rotate and the filament is being wound on the package, and consequently, it is important that the traveller speed be maintained within a certain range during this latter part of the start-up period, when the draw rolls are rotating.

Although the traveller speed of the yarn guide should at no time during this period be permitted to exceed the highest speed of the range it should start at this speed when the draw rolls have started to rotate, or rise to it soon after they have started to rotate. As a result the traveller speed will then fall to a value near to its minimum acceptable speed when the draw rolls have obtained their maximum speed.

In this way the balloon tension is given its maximum possible value initially, which is found to cause a reduction in the number of filament breakages. The spindles are arranged to obtain their maximum speed, i.e., their requisite speed according to the winding programme at the end of the start-up period, either at the same time as or before the draw rolls have obtained their corresponding maximum speed.

During the start-up period in each package winding cycle, it is usual to arrange for a waste bunch to be wound, particularly as the filament at this point may be inadequately drawn or otherwise processed.

The time taken for the draw rolls to be brought up to speed should be as short as possible, for productivity reasons, and such that the waste bunch, which is wound during this time, is not too large.

Throughout the major part of the winding operation, when the winding apparatus is operating in a normal manner, the A.C. motor is arranged to drive the draw rolls at a constant speed, which speed is related to the desired processing speed for the apparatus.

However, the D.C. motor is arranged to drive the spindles according to a predetermined winding programme during this period, in order that some desired object, with respect to the winding operation, may be obtained.

For example, the spindle speed may be arranged to be reduced throughout the winding operation in a manner which maintains the balloon tension at a constant value by arranging that the ratio of the square of the traveller speed to the package diameter is constant throughout. In any event the balloon tension is maintained at a value in the range 0.1 to 0.5 gram per denier during the winding operation, otherwise the balloon tension may change by as much as 250%.

Thus, it is desirable throughout the winding operation of a yarn of 40 denier polyhexamethylene adipamide, for instance, that the traveller speed is maintained at a value in excess of 2500 r.p.m. but preferably below 4000 r.p.m.

By this means, the balloon formed by the over-end winding apparatus will be stable throughout the whole of the winding operation, the manner in which the filament is laid on the package will be predictable, and the balloon tension will be maintained within the desired narrow range of values. In this way, barre and warp stripiness will be reduced, if not eliminated, in the fabrics into which a filament wound in this way is eventually made-up.

Thus, the spindle speed can be arranged to be varied throughout the winding of a package in accordance with the profile of a cam embodying the desired spindle speed programme.

The D.C. motor driving the spindles is arranged to be controlled by a servo device, which in turn is controlled by the cam, this cam being arranged to be rotated at a constant speed by being rotatably mounted on the shaft comprising the ring-rail traverse cam drive means.

The servo control device for the D.C. motor comprises a 3-phase magnetic amplifier, the input of which is controlled by a pre-amplifier. The motor armature voltage comprises the output from the magnetic amplifier, and the current from a rectifier positioned across one phase of the electrical supply to the device comprises the shunt field excitation current for the motor.

The programming cam is used to produce a reference signal, which varies in accordance with the winding programme, and the spindle speed is monitored continuously by means of the first tacho-generator operably coupled to the output shaft of the D.C. motor. The reference error unit compares the signal from the first tacho-generator with the reference signal.

The error signal obtained by this comparison is then used to alter the output of the D.C. motor by being fed to the pre-amplifier of the servo control device and so alters the magnitude of the current fed to the armature of the motor.

The cam follower comprises the slider of a linear potentiometer, and the output from this potentiometer is the reference signal.

Trimming rotary potentiometers are provided at each end of the linear potentiometer of the programming means, each such rotary potentiometer having a range approximately 20% of the linear potentiometer range and being

used to control the effective range of the linear potentiometer.

It is essential that the balloon tension be maintained within a similar narrow range of value during the slow-down period also, so that breakages may be reduced or avoided during this period.

The optimum slow-down conditions required to be reproduced by the winding apparatus in winding a yarn of 40 denier polyhexamethylene adipamide, for instance, are that the traveller speed shall not fall below 2500 r.p.m. while the draw rolls are rotating and the filament is being wound in order that a stable balloon may be maintained and that the spindles shall be brought to rest as soon as practicable after the draw rolls whereby there will be a reduction in the number of filament breakages and loops.

Due to the relatively high inertia of the motors coupled respectively to the spindles and the draw rolls, both the spindles and the draw rolls will tend to run-on when the motors are de-energised, and in any event they will decelerate at rates which are independent of each other.

Thus, at the start of the slow-down period, the A.C. motor driving the draw rolls may be switched-off so that the draw roll speed is allowed to decay normally.

In order that there should be the controlled predetermined relationship between the spindle speed and the draw roll speed during the first part of the slow down period the second tacho-generator is provided to monitor the speed of the draw rolls, and during the first part of the slow-down period, the output signal from this second tacho-generator is fed to the reference error unit.

The connection of the second tacho-generator to the reference error unit, and the disconnection of the programme cam potentiometer therefrom, is caused by the programming means upon the transference of the winding apparatus from its normal operating procedure to its slow-down procedure. (Compare FIGURES 3 and 4.)

The reference error unit compares this signal with that from the first tacho-generator monitoring the spindle speed, and feeds back a signal to the D.C. motor to drive it, so that the two motors slow down at a predetermined ratio.

The programming means causes another signal to be compounded with the above-mentioned signal, the magnitude of which second signal is such that, alone, it would cause the spindles to be driven at above the minimum value of, say, 2500 r.p.m.

This second signal is produced by a "traveller speed" potentiometer which is positioned across a fixed voltage. When the apparatus is idle, this potentiometer is adjusted to give the desired voltage determined empirically previously, and the programming means places this potentiometer across the first tacho-generator, which is coupled to the D.C. motor drive shaft, when the slow-down procedure is initiated.

In most winding programmes the traveller speed will be near to the minimum acceptable value (i.e., 2500 r.p.m. for 40 denier yarn) at the start of the slow-down period.

The above referred-to programme for the slow-down period of the package winding cycle is shown graphically in FIGURE 2, in which the full lines indicate the actual speed/time programmes of the spindle and draw rolls respectively, and in which the dotted line indicates the speed/time programme for the spindle corresponding to the first component of the predetermined relationship of spindle speed to draw rolls speed.

In order to ensure that, when the winding apparatus changes over from the normal operating procedure to the slow down procedure, there is no sudden jump in the D.C. motor speed or traveller speed, and the winding apparatus begins smoothly to slow down, there is provided a "change-over speed" potentiometer positioned across the second tacho-generator, i.e., that which is operably coupled to the draw rolls. During the initial setting-up of the apparatus, with the apparatus running, and the spindle speed arranged to be the value at which the slow-down procedure is to be initiated, this potentiometer is adjusted so that no signal is fed from the second tacho-generator to the reference error unit.

As already mentioned, in order that a positive control may be maintained it is advantageous to arrange that the spindles are driven against lightly-applied braking pressure during the first part of the slow-down period.

Thus, upon the transference of the winding apparatus from its normal operating procedure to its slow-down procedure, the programming means is arranged to actuate the spindle break means, and during the initial setting-up of the winding apparatus, with the apparatus operating and with the brake means in this position, this means is adjusted so that the D.C. motor armature current is at a low, finite, but detectable value. Hence, the spindle drive means will not "hunt" during the first part of the slow-down period.

The zero-speed sensing device coupled to the second tacho-generator is arranged also to control the spindle braking means. The arrangement is such that, when the sensing device detects that the second tacho-generator is registering zero-speed for the draw rolls, the sensing device causes the spindle braking means to be actuated to cause maximum braking restraint to be applied to the spindles, which is the condition required to avoid the occurrent of "slow-down loops" on the package being wound.

The sensing device is also operably coupled to the spindle drive means servo device during the slow-down period, and upon the activation of the braking means by the sensing device, at the end of the first part of this period, the sensing device simultaneously causes the de-energisation of the D.C. motor driving the spindles. Thus, there is nothing counter-acting the torque applied by the braking means on the spindles.

Thus, during the slow-down period in each package winding cycle the manner of operation of the D.C. motor is positively programmed so as to avoid the occurrence of both filament breakages and loops during this period.

A second variable timer is included in the apparatus so that the movement of the ring rail of the winding apparatus is controlled during the slow-down period. In view of the fact that the draw rolls are allowed to run down freely, it is important that the ring rails should not be brought to rest before the slow-down bunch has been wound onto the bobbin. Thus, by use of this second timer, the ring rail is stopped at a predetermined time after the initiation of the slow-down programme, this delay being such that the ring rail is stopped after the draw rolls have stopped. The spindles tend to run-on after this time, even under maximum braking forces, particularly if relatively large packages are being wound at relatively high speeds.

In this particular embodiment according to the present invention, the following operating conditions were employed for a draw-twist machine drawing 40 denier polyhexamethylene adipamide yarn having 13 constituent filaments, the machine operating at a drawing speed of 4200 feet per minute.

During the start-up period

The timer delaying the start of the A.C. motor driving the draw rolls was set at a value in the range 3.0 to 5.5 seconds, say 4 seconds, and the acceleration of the draw roll was such that it reached its maximum peripheral speed of 4200 feet per minute, say 3000 r.p.m., in a further 4.0 seconds. The spindles accelerated to 3000 r.p.m. in 1 second and reached maximum speed of 11,000 r.p.m. in 8 seconds.

No filament breakages occurred, nor did a filament twist off the draw rolls during the start-up period. The maximum twist insertion was 9.5 t.p.i., but this was reduced to the normal acceptable level, say 1.0 t.p.i., by the time the ring rail had passed the waste bunch.

During the slow-down period

The draw rolls were allowed to run down freely under their own inertia from 3000 r.p.m., taking 15 seconds to do this. The spindle brake was adjusted so that the spindles which were rotating at 7200 r.p.m., would have stopped with the draw rolls, except that the D.C. motor driving the spindles is arranged to drive the spindles at 250 r.p.m. even when the draw rolls are stopped.

The spindle brake is then adjusted to apply a maximum braking torque to the spindles and these are then brought to rest in a further 2 seconds, the D.C. motor having been cut off simultaneously with the application of the maximum braking torque to the spindles.

The occurrence of filament breakages during the slow-down period was eliminated, and the slow-down loop formation rate reduced to less than 1% of the total number of times a package winding cycle had been started, compared to a value of over 20% in one particular filament winding process.

The accuracy with which the predetermined start-up and slow-down programmes were reproduced by the apparatus described above was ±½%, which was the accuracy of the motors employed. This was found to be adequate and the beneficial effects, referred to above as being obtainable by use of the apparatus according to the present invention, were found.

In practice, it is found that there is a range of several seconds during which the spindles may come to rest, for a given slow-down period for the draw rolls, and in which range neither slow-down breakages nor loops occur. At speeds above 7000 r.p.m. the traveller becomes subject to excessive stresses, and this speed was therefore never exceeded.

In operation, the spindle brake was found not to need readjustment over a considerable period of operation of the machine; while in conventional equipment of this type the spindle brake would require re-setting at intervals of approximately 3 months.

It will be appreciated that the quality of yarn packages produced on apparatus according to the invention will be improved, and the yarn wound thereon will have greater uniformity, compared with what has been possible heretofore without an excessively high wastage rate associated with each machine.

In addition, the apparatus allows for considerable flexibility in the manner in which it may be used, while still being capable of giving the benefits occurring from the use of the present invention.

The spindle speed programme embodied in the cam, in the embodiment described above, may be modified by incorporation of a rotary potentiometer arranged cyclically to vary the spindle speed throughout the winding operation, so that the manner of lay of the filament onto the package is scrambled.

The winding apparatus described above is simple in form and is self-correcting for variations in the loading of the apparatus.

We claim:

1. A method of winding a yarn package on over-end winding apparatus in a manner to minimize slow-down breakages and loops, comprising the steps of:
   (a) positively forwarding yarn by draw rolls to a rotating spindle for winding thereon in the form of a yarn package,
   (b) stopping said draw rolls independently of said spindle when a full yarn package has been wound,
   (c) programming the slow-down period of the full package winding cycle in such manner that the spindle speed is positively controlled in a predetermined relationship to the draw rolls speed during the first part of said period until the draw rolls become stationary, and

   (d) bringing said spindle to rest after the draw rolls have become stationary.

2. A method of winding a yarn package on over-end winding apparatus including draw rolls and a spindle in a manner to minimize defects due to start-up and slow-down, comprising the steps of:
   (a) programming the start-up period of the full package winding cycle in such manner that the draw rolls are started to rotate a predetermined time interval after the spindles have been started to rotate,
   (b) winding a full yarn package on said spindle by positively feeding yarn thereto from said draw rolls,
   (c) stopping said draw rolls independently of said spindle,
   (d) programming the slow-down period of the full yarn package winding cycle in such manner that the spindle speed is positively controlled in a predetermined relationship to the draw rolls speed during the first part of said period until the draw rolls become stationary,
   (e) bringing said spindle to rest after the draw rolls have become stationary.

3. A method of winding a yarn package according to claim 2, in which the full yarn package is wound during the main winding period, by driving the draw rolls at a constant speed and by driving the spindle separately therefrom and according to a predetermined programme.

4. A method of winding a yarn package according to claim 3 in which the predetermined programme for the spindle drive includes a cyclical variation of the spindle speed.

5. Over-end winding apparatus of the kind in which yarn is fed to a rotating spindle from processing rolls, said apparatus including:
   (a) a motor adapted to drive the spindle,
   (b) a second motor adapted to drive the draw rolls independently of the spindle,
   (c) programming means for controlling the winding operation of the apparatus in a positive manner at least during the slow-down period of the full package winding cycle, said means including a servo device for controlling the spindle drive motor, a first tacho-generator for the spindle and a second tacho-generator for the draw rolls, and a reference error unit adapted to compare electrical signals produced by said tacho-generators during said slow-down period and to feed a resultant electrical signal therefrom to said servo device.

6. Over-end winding apparatus according to claim 5, and including a zero speed sensing device adapted to receive electrical signals from said second tacho-generator and to activate said servo device to stop the spindle drive on sensing zero speed.

References Cited

UNITED STATES PATENTS

2,682,144	6/1954	Hare	57—93 XR
3,009,308	11/1961	Bromley et al.	57—55.5
3,137,987	6/1964	Potts	57—93 XR
3,277,641	10/1966	O'Donahue et al.	57—93 XR
3,316,699	5/1967	Mattingly	57—93
3,325,985	6/1967	Bucher	57—93

FOREIGN PATENTS

946,240	1/1964	Great Britain.

STANLEY N. GILREATH, *Primary Examiner.*

W. H. SCHROEDER, *Assistant Examiner.*