



(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
06.12.2000 Bulletin 2000/49

(51) Int Cl.7: B65H 54/28

(21) Application number: 00201890.1

(22) Date of filing: 29.05.2000

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

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(30) Priority: 31.05.1999 IT MI991213

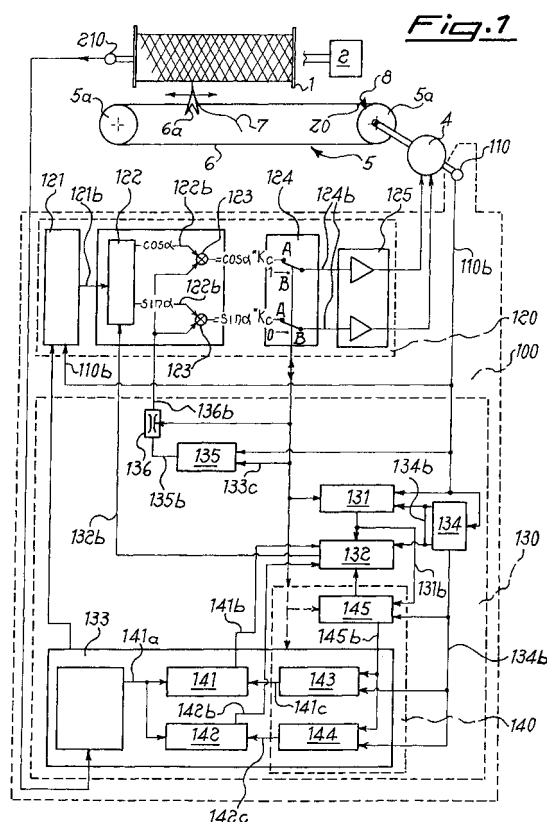
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(54) Method and apparatus for controlling the winding of threads and the like onto rotating supports such as reels of yarn and the like

(57) Apparatus for controlling the alternating movement of a thread guide (6a) which is actuated by an electric motor (4) via means (5a,5b,6) supporting the said thread guide and is intended to wind a thread (7) onto rotating supports (1), comprising

- an angular transducer (110) for detecting the angular position of the rotor (4a) of the motor (4);
- a device (120) for vectorial control of the currents supplied to the motor (4);
- a circuit (130) for controlling the speed of rotation of the rotor (4a), which is connected to the angular transducer (110) and to the vector control circuit (120).



Description

[0001] The present invention relates to a method and an associated apparatus for controlling the winding of threads and the like onto rotating supports such as reels for weaving and the like.

[0002] It is known that in the weaving industry every process which is performed using thread results in the need to store the said thread so that it is available in the most convenient form for subsequent operations.

[0003] One of the most common and widely used forms of storage consists of the so-called reel, namely a cylindrical element onto which the thread is wound so as to produce a spool (or reel) which must have precisely determined characteristics - such as the diameter, weight, shape, unwinding precision and speed - which are those used for defining the greater or lesser adaptability of a certain type of reel for subsequent processing which may require a high unwinding speed or an unwinding tension which is as small as possible, or a uniform density or high volume.

[0004] It is also known how said characteristics are substantially determined by the reel winding methods and conditions, said winding having to be, however, as fast and precise as possible.

[0005] Said winding is essentially performed by fastening one end of a thread to a cylinder supporting the reel and by causing rotation of the said cylinder by means of a controlled motor; the thread is simultaneously inserted into a guiding element (thread guide) which is actuated so as to perform an alternating rectilinear movement with a trajectory parallel to the axis of the cylinder.

[0006] It is also known that winding of the thread onto the reel produces two main control-related problems arising from:

- the need to keep the time required for reversing the movement of the thread guide as small as possible so as to achieve the highest possible winding speed and
- the need to ensure the maximum precision of the thread reversal point, namely the point where the thread completes an outward winding cycle and starts the return winding cycle; control of the reversal position is of critical importance for preventing separation of the thread from the reel or, vice versa, overlaying of the thread (ribbing), which are the direct cause of breakage of the thread and/or incorrect unwinding of the reel during subsequent processing.

[0007] In order to achieve control of the two above-mentioned parameters, solutions based on the use of stepper motors have been proposed, said motors being operated by means of controlled and programmed sequences of pulses which, varying in frequency, perform slowing down and reversal of the movement of the

thread guide as well as compensation of any errors in the reversal point.

[0008] This technique is known, for example, from EP 0,453,622.

[0009] Although fulfilling their function, these solutions, however, have certain drawbacks arising from the use of pulse-controlled stepper motors which, since there is no bi-univocal correspondence between the stator current and the torque produced, generate pulsating torques which are the cause of electrical and mechanical resonance which arise at given frequencies, producing stoppage of the motor and, at the same time, causing loss of all the information relating to the position of the thread guide, said information having to be subsequently restored.

[0010] In order to eliminate these problems, common practice envisages using only 70% of the motor's rated power during winding of the thread and keeping the remaining 30% available for overcoming the said blockage points as quickly as possible.

[0011] The use of only 70% of the available power, however, reduces the possibility of obtaining the high accelerations (braking torque) which are necessary for reducing the time required for reversing the movement of the thread guide. Moreover, the use of a pulse-control system, which depends solely on the frequency of the said pulses, requires that the current which is supplied to the motor must be kept at a value higher than that which would actually be necessary, since an excessive reduction in the said current would not leave a safety margin for preventing loss of the step sequence and consequent stoppage of the apparatus, should there be random increases in the resistance torque due, for example, to the irregular nature of the thread.

[0012] The technical problem which is posed, therefore, is that of providing a method and an associated apparatus for controlling devices for guiding and laying yarns and the like to be wound onto cylindrical supports for forming a reel, which are able to minimize the time required for reversing the direction of movement of the thread guide, thereby overcoming the abovementioned problems associated with pulse-controlled stepper motors.

[0013] Within the scope of this problem a further requirement is that the method and the associated apparatus should be able to control with a high degree of repeatability the precision of the thread winding reversal point and that this control should be such as to allow easy and rapid variation of the associated parameters in relation to the different types of winding required. These technical problems are solved according to the present invention by an apparatus for controlling the alternating movement of a thread guide which is actuated by an electric motor via means supporting the said thread guide and is intended to wind a thread onto rotating supports, comprising an angular transducer for detecting the angular position of the rotor of the motor, a device for vectorial control of the currents supplied to

the motor, and a circuit for controlling the speed of rotation of the rotor, which is connected to the angular transducer and to the vector control circuit.

[0014] The present invention also relates to a method for controlling the alternating movement of a thread guide which is actuated by an electric motor via means supporting the said thread guide and is intended to wind a thread onto rotating supports, comprising the steps of detecting the angular position of the rotor of the motor, sending corresponding signals to a circuit controlling the currents supplied to the motor and to a circuit controlling the speed of the thread guide, vectorial control of the currents supplied to the motor and control of the speed of the thread guide.

[0015] Further details may be obtained from the following description of a non-limiting example of embodiment of the invention, provided with reference to the accompanying drawings in which:

- Figure 1 shows the diagram of a first embodiment of the apparatus for winding yarns with associated means for controlling the speed of the thread guide;
- Figure 2 shows the detailed diagram of the circuit for vectorial control of the motor;
- Figures 3a,3b show a linear representation of the movement of the thread guide and the signals for controlling the speed alone;
- Figure 4 shows the diagram of a further embodiment of the apparatus according to the invention with control of the speed of rotation and position for reversal of the thread guide movement;
- Figures 5a,5b show a linear representation of the movement of the thread guide and the signals controlling the speed and the position of the thread guide.

[0016] As illustrated in Fig. 1, a spooling machine of the known type essentially comprises a spool or reel 1 which is rotationally driven by a motor 2, optionally via a drive roller (not shown), and a thread guiding device comprising a second motor 4 (in the example of the two-phase type) which is independent of the first motor and connected to a first pulley 5a of the thread guiding device 5 which also comprises a second pulley 5b and a belt 6 endlessly wound around said pulleys and supporting the cursor 6a through which the thread 7 passes.

[0017] The motor 4 is of the multiple-pole type and may be of the stepper type or so-called brushless type.

[0018] The rotational operation, in both directions, of the pulley 5a - and therefore the belt 6 - causes the alternating linear movement of the cursor 6a and consequently the outward/return cycle of the thread which is wound onto the reel.

[0019] Said alternating movement (Fig. 3a) is performed between two ends (reversal points) X0 and X3 which are chosen according to the programmed winding parameters and determined with reference to a predefined "absolute zero" position of the machine; as shown

in Figs. 1 and 3a, in a preferred embodiment, said reversal points are both on the same side with respect to the said absolute zero Z0 which forms the reference point for the entire machine.

[0020] In the example shown, said absolute zero consists of a mechanical stop (or position sensor) 8 which is arranged beyond the right-hand reversal position for winding of the thread 7.

[0021] The apparatus 100 for controlling winding comprises a first detection device consisting of an angular transducer 110 which in the example is formed by an incremental encoder and is able to detect the angular position of the rotor 4a of the motor 4 and send corresponding electric signals to a circuit 120 for vectorial control of the currents supplied to the stator 4b of the motor 4; the same signals of the encoder 110 are also sent to a circuit 130 for controlling the speed of rotation of the motor 4.

[0022] In greater detail, the circuit 120 for vectorial control of the currents comprises:

- a circular counter 121 which, for example, is dimensionally designed so as to count sixty four pulses per revolution and which:
 - receives at its input a signal 110b which is emitted by the encoder 110 in relation to the angular position of the rotor 4a;
 - and emits at its output a signal 121b corresponding to angular values α which represent the angular position of the rotor and increase/decrease in relation to the direction of rotation of the rotor and which are sent:
- to a block 122 for converting said values of α into corresponding cyclically repeated sine and cos values of α able to send corresponding signals 122b;
- to a first input of a pair of multipliers 123 which receive at a second input a signal 135b emitted by the speed control device 135; said multipliers therefore determine the value of the modulus of the two vectors of the current supplied to the respective stator windings;
- a switch 124 which is able to assume two positions A and B respectively for normal continuous control and initial phase synchronization, respectively, (described in detail below) and the outputs 124b of which are supplied to:
- a power circuit 125 for supplying the currents to the motor 4.

[0023] As mentioned, by means of the vector control circuit 120 it is possible to perform also initial phase synchronization of the device suitable for determining output, by the motor, of the maximum available torque for each angular position of the rotor.

[0024] Said phase synchronization of the maximum torque is obtained by ensuring that the vector represent-

ing the vectorial sum of the stator magnetic fields is always perpendicular to the vector of the rotor magnetic field.

[0025] Essentially (Fig. 2), whenever the machine is switched on, it is required to define an angle between the two fields such as to determine the maximum torque operating condition; for this purpose:

- the switches 124 are switched to position B where:
- the maximum current value is defined in the stator winding 4c and
- the current value in the stator winding 4d is zeroed;
- in these conditions, after a few fractions of a second, the rotor is aligned with the maximum current winding,
- and it is possible to set the counter 121 to the numerical value (16, if the counter is a 64-pulse counter) corresponding to an angle α which is phase-displaced by 90° with respect to the existing alignment position; in this way the counter 121 will output signals corresponding to the detected angular value displaced by $+90^\circ$, imposing this angular phase displacement for each point of rotation of the motor, in order to maintain the desired maximum torque condition;
- once phase synchronization has been obtained, the currents are reset to zero and the switch 124 is again switched to position A in order to start normal control of the winding cycle.

[0026] In the case of motors with more than two phases, a similar procedure is adopted, taking into account the angular position of the resultant of the stator field. It is also envisaged that initial phase synchronization may alternatively be implemented by means of control of the counter 121 - or its output 121b - performed by the calculation unit 133.

[0027] The circuit 130 controlling the speed of the rotor 4a - and therefore that of the thread guide 6a - is, as mentioned, based on the encoder 110 and comprises:

- a device 134 for detecting the direction of movement of the rotor 4a which, depending on the sequence of signals 110b sent to its input by the encoder 110, is able to emit a signal 134b representing the direction of rotation of the rotor - and hence the direction of movement of the thread guide 6a - which is sent to a first input of:
- a counter 131
 - which receives at a second input the pulses 110b which are emitted by the encoder 110 and are counted and stored so as to generate a counting signal 131b representing the existing position of the rotor 4a and therefore that of the thread guide 6a;
 - an existing position comparator 132 which receives at its input:

- the signal 131b emitted by the counter 131,
- the signal 134b emitted by the direction of movement detector 134,
- two signals 141b and 142b emitted by a pair of calculation units 141, 142 associated with the central processing unit 133 and representing the calculated position of the points X2, X5 where it is required to reverse the torque,

- emits a corresponding signal 132b which represents the direction of the torque required for that unwinding section and which is sent to the register 122 of the vector conversion circuit 120.

[0028] At the same time, the signal 110b of the encoder 110 is also sent to the speed control and regulation device 135 which, receiving at its input:

- also a signal 133c emitted by the unit 133 and representing the speed programmed for the specific winding section,

emits a current signal 135b corresponding to the torque value required in order to reach and maintain the intended speed along the existing trajectory section.

[0029] In this way the vector conversion circuit is able to control both the modulus and the direction of the torque which must be output by the motor 4 in order to obtain the speed value of the thread guide required for the specific situation along the travel path of the said thread guide.

[0030] Since the encoder 110 is of the incremental type, all the control is also of the incremental (i.e. non-absolute) type and, whenever the machine is switched off, memorization of the position of the thread guide 6a with respect to the absolute zero 8 of the machine is lost, said memory having consequently to be restored whenever the apparatus is switched on.

[0031] For this purpose, the counter 131 is set, at each switch-on, using the following procedure:

- a small torque and speed value are set by means of a limiting device 136 in order to prevent mechanical damage to the thread guide when it comes into contact with the mechanical stop 8;
- the thread guide is displaced until it stops in abutment against the absolute-zero mechanical stop 8,
- after lapsing of a certain predefined maximum time interval - or alternatively when there is the prolonged absence of pulses from the encoder 110 - a signal indicating that stoppage has occurred is sent to the central control unit 133 which, in turn, resets the counter 131, restoring the reference value of the apparatus,
- from this moment the sequence of pulses 110b emitted by the encoder 110 determines the location of the existing position and the direction of displacement of the thread guide 6a.

[0032] In the exemplary case of reversal points arranged on the same side with respect to the absolute zero, in order to start the actual spooling cycle, the direction of movement of the thread guide is reversed, checking that the value of the counter 131 is equal to the value 133b programmed to start winding and sent to the counter:

- for as long as the two values are different, the thread guide continues to advance and the motor maintains a certain torque value;
- when the two values are the same (starting point reached), the torque is reduced to zero and the signal for starting spooling is awaited.

Since the speed of the thread guide and the presence of unpredictable variables such as friction, tension, vibration and the like affect operation of the machine such that the thread guide reverses its travel movement not exactly at the predefined points X0,X3, but at points which may be before (negative error or underestimation) or after (positive error or overestimation) these programmed points X0,X3, the operating and control apparatus 100 also comprises a circuit 140 for correcting said reversal error. Said circuit 140 comprises:

- a device 145 for measuring the error in travel through the reversal point,
- a pair of corresponding storage units 143,144 designed to store the respective the right-hand or left-hand error which has occurred during winding. In greater detail, the error measuring device 145 receives at its input:
 - the signal 134b emitted by the circuit 134 for detecting the direction of movement,
 - the counting signal 131b emitted by the counter 131 and
 - the associated signal emitted by the processing unit 133 and corresponding to the set value of the reversal points X0,X3;
 and outputs:
 - a signal 145b corresponding to the value of the error measured during travel through the reversal points;

said signal 145b is sent to the respective right-hand storage unit 143 or left-hand storage unit 144 which in turn emits a corresponding signal which is sent to the input of the associated calculation units 141,142 which, receiving at their input also a pre-set initial error signal 141a (for the sake of convenience the same on the right and on the left), performs calculation of the new value of the switching points X2,X5 for which the reversal error is minimized during the next travel stroke.

[0033] In other words, the apparatus is able to displace, with each travel stroke, the torque reversal points X2,X5 depending on the error in the reversal point de-

tected during the previous travel stroke.

[0034] This calculated value 141b,142b is input into the position comparator 132b which in turn provides the new torque direction signal 132b.

[0035] The operating principle of the apparatus (Figs. 1, 3a,3b) is as follows:

- the processing parameters for the specific form of the reel to be produced are defined (speed of rotation of the reel, number of turns, angle of lay, angle between turns, etc.),
- the following are also established:
 - the position of the reversal points X0,X3 with respect to the absolute zero,
 - the maximum programmed speed for the thread guide 6a in relation to processing (of the thread) in progress;
 - the initial error.

[0036] This initial error is introduced specifically in order to determine two initial switching points, and hence reversal points, which are definitely located internally with respect to the two actual reversal points X0,X3, thus ensuring that the reversal error during the first rotation is definitely an underestimation error such as not to move the thread beyond the maximum dimension of the reel, with consequent breakage of said thread and blockage of the apparatus;

- the following preliminary operations, already described, are performed:
 - vectorial phase synchronization in order to determine the maximum torque condition,
 - detection of the absolute zero with initialization of the counter 131,
 - positioning of the thread guide in a position between the reversal points.

[0037] Starting the winding cycle and assuming winding in the clockwise direction, the speed control device 135 will initially request the maximum torque available in order to bring the thread guide 6a, which is at a standstill, to the programmed working speed which is maintained until the thread guide reaches the predefined, right-hand, first switching point X2 which is calibrated by means of the initial error introduced by the operator and is detected by the position comparator 132 and where the said comparator 132 causes reversal of the direction, adding 180° to the actual value of a detected and sending the corresponding signal 132b to the conversion block 122.

[0038] This reversal causes braking of the motor and hence a reduction in the speed of the thread guide which is detected by the speed control circuit which reacts by requesting greater torque in order to compensate for the slowing down effect; in this way, since the torque is di-

rected in the opposite direction to the direction of rotation of the motor, the thread guide is brought to zero speed at the reversal point X3 where the direction of its movement is reversed, said movement thereby matching the torque which, from this point, pushes the thread guide so as to reach the programmed speed 133c for the linear return section.

[0039] The programmed speed is reached at the point X4 where the speed control circuit reduces the required torque signal, keeping it at the minimum value necessary for maintaining the speed as far as the first left-hand reversal point X5 which is calibrated by the initial error introduced by the operator and where the torque reversal cycle and then the thread guide movement reversal cycle are repeated when the reversal point X0 is reached.

[0040] When the two reversal points, i.e. the right-hand reversal point X0 and the left-hand reversal point X3, are passed through, the respective error calculation circuits 141, 142 detect the underestimation of the reversal point X0, X3 and set the new value of X2, X5 which compensates for the initial error set so that, as from the second rotation, reversal of the movement occurs at the predefined reversal points less the intrinsic error of the apparatus.

[0041] In the case where greater precision is required with regard to attainment of the points for reversal of the movement of the thread guide 6a, compensating for any errors, due to external causes, between one detection operation and the next, it is envisaged that the control apparatus may also comprise a position control device 150 which intervenes, in place of the speed control circuit 135, along the section respectively lying between the right-hand switching point X2 and left-hand switching point X5 and the associated reversal point X0, X3.

[0042] In greater detail and with reference to Figs. 4, 5a, 5b, said position control device comprises:

- means 151 for disabling the speed control system and enabling the position control system, represented by way of example in the figures by a switch which is able to switch from a position for enabling the speed control circuit 135 to a position for enabling:
- a position control circuit 152 which receives at its input:
 - a reference signal 133f representing the programmed position for the reversal point X0, X3;
 - a signal 131b which indicates the existing position of the thread guide 6a and is sent from the counter 131;
 - an existing speed signal 135f.

[0043] In this way the circuit 152 is able to perform the following:

- + detect continuously, along the section X2-X3 or

X0-X5, the difference D between the programmed value of X0, X5 and the existing value of the thread guide position;

- + compare the corresponding existing speed value with the programmed speed value for that point;
- + calculate the relevant difference δV between said speeds;
- + intervene so as to generate a signal 152b for varying the modulus of the torque which may be increased/decreased depending on the sign of the difference δV detected.

[0044] In a simplified alternative embodiment of the position control device, it is also possible to perform variation of the torque 152b in accordance with a graph which is a function of the sole variable D instead of the variable δV .

[0045] Basically the position control device causes a short slowing down transient for the thread guide which allows the correction of any imprecision accumulated during the travel thereof, which is controlled only in terms of speed, as well as attainment of the programmed reversal point with a high degree of precision.

[0046] Once the reversal point X0, X3 is reached (D=0), the control device 133 again switches the switch 151 to the speed control device 135 which, finding a zero speed, instantaneously recalls the maximum torque value so as to adjust as rapidly as possible the speed of the thread guide to the programmed travel speed and resume normal control of the thread guide.

[0047] As illustrated in Fig. 1, it is also envisaged that the apparatus may comprise a second encoder 210 which is located between the reel 1 and the calculation unit 133 and by means of which it is possible to control the speed of the thread guide according to the speed of the reel and/or another parameter external to the control apparatus, so as to produce windings of a special type. It is therefore obvious how, with the apparatus according to the invention, it is possible to reverse the direction of the torque when the speed of the thread guide is still at a maximum level, thereby achieving a reduction in the time required for reversal of the thread guide movement; moreover, with the speed control system according to the invention it is possible to limit the current supplied to the motor to the minimum value required, limiting the dissipation phenomena and therefore wear of the said motor.

Claims

1. Apparatus for controlling the alternating movement of a thread guide (6a) which is actuated by an electric motor (4) via means (5a, 5b, 6) supporting the said thread guide and is intended to wind a thread (7) onto rotating supports (1) characterized in that it comprises

- an angular transducer (110) for detecting the angular position of the rotor (4a) of the motor (4);
 - a device (120) for vectorial control of the currents supplied to the motor (4);
 - a circuit (130) for controlling the speed of rotation of the rotor (4a), which is connected to the angular transducer (110) and to the vector control circuit (120).
2. Apparatus according to Claim 1, characterized in that said angular transducer (110) is an encoder.
 3. Apparatus according to Claim 1, characterized in that said angular transducer is of the incremental type.
 4. Apparatus according to Claim 1, characterized in that said device for vectorial control of the currents comprises at least one bidirectional counter (21) for counting and memorizing the pulses (110b) of the angular transducer (110).
 5. Apparatus according to Claim 1, characterized in that said device for vectorial control of the currents comprises at least one vector conversion circuit formed by a conversion block (122) and by at least one pair of multipliers (123) which receive an input signal from the speed regulation circuit (135).
 6. Apparatus according to Claim 1, characterized in that said device for vectorial control of the currents comprises means (124) for switching from a normal operating condition (A) to an initial phase synchronization condition (B).
 7. Apparatus according to Claims 1 and 6, characterized in that, in phase synchronization conditions, said counter (121) is set to a value corresponding to a phase displacement of 90° between the vector representing the vectorial sum of the stator magnetic fields and the magnetic field of the rotor (4a).
 8. Apparatus according to Claim 1, characterized in that said speed control circuit (130) comprises at least one bidirectional counter (131) for counting and memorizing the pulses (110b) of the angular transducer (110).
 9. Apparatus according to Claim 8, characterized in that said speed control circuit comprises a direction of movement detector (134) and a position comparator (132) able to generate a directional signal (132b) for the torque to be output, which is sent to the input of the vector control conversion block (122).
 10. Apparatus according to Claim 8, characterized in that it comprises a speed regulation device (135) designed to emit said signal (132b) regulating the modulus of the current supplied to the motor (4).
 11. Apparatus according to Claim 1, characterized in that it comprises a circuit (140) for detecting and compensating for the error in the right-hand reversal point (X0) and left-hand reversal point (X3).
 12. Apparatus according to Claim 11, characterized in that said error compensation circuit comprises at least one pair of calculation units (141, 142) which are designed to calculate the subsequent torque reversal point (X2, X5) and emit corresponding signals (141b, 142b) to be sent to the comparator (132).
 13. Apparatus according to Claim 12, characterized in that it comprises a right-hand and left-hand error measuring device (145) and at least one unit (143) for storing this error.
 14. Apparatus according to Claim 13, characterized in that said storage devices are two in number (143, 144).
 15. Apparatus according to Claim 1, characterized in that it comprises a position control circuit (150) able to modify the conditions for approaching the reversal point.
 16. Apparatus according to Claim 15, characterized in that said position control circuit comprises means (151) for enabling position control and disabling speed control and vice versa and a torque regulator (152).
 17. Apparatus according to Claim 16, characterized in that said torque regulator (152) receives at its input the signal (131b) of the position counter (131), a reference signal (133f) corresponding to the programmed reversal point (X0, X3) and a signal (135f) indicating the existing speed of the thread guide and emits a signal (152b) indicating the modulus of the torque to be sent to the vector control circuit.
 18. Apparatus according to Claim 17, characterized in that said signal (152b) emitted by the regulator (152) is a function of the difference (D) between the programmed reversal point and the existing position.
 19. Apparatus according to Claim 17, characterized in that said signal (152b) emitted by the regulator (152) is a function of the difference in speed (6V) between the programmed speed and the speed detected in the existing position (D).
 20. Apparatus according to Claim 1, characterized in

that it comprises a second angular transducer (120) located between the reel (1) and the calculation unit (133).

21. Apparatus according to Claim 1, characterized in that said motor (4) is a multiple-pole motor. 5

22. Apparatus according to Claim 21, characterized in that said motor is a stepper motor. 10

23. Method for controlling the alternating movement of a thread guide (6a) which is actuated by an electric motor (4) via means (5a,5b,6) supporting the said thread guide and is intended to wind a thread (7) onto rotating supports, comprising the steps of: 15

- detecting the angular position of the rotor (4a) of the motor (4) via associated means (110);
- sending corresponding signals to a circuit (120) controlling the currents supplied to the motor (4) and to a circuit (130) controlling the speed of the thread guide; 20
- vectorial control of the currents supplied to the motor;
- control of the speed of the thread guide (6a). 25

24. Method according to Claim 23, characterized in that said detection of the angular position of the rotor (4a) of the motor (4) is performed by means of an angular transducer (110). 30

25. Method according to Claim 24, characterized in that said transducer (110) is incremental.

26. Method according to Claim 23, characterized in that it envisages the following steps: 35

- counting and memorizing the signals relating to the angular position of the rotor;
- generating corresponding counting signals; 40
- vectorial conversion of said counting signals;
- multiplication of said converted signals by a torque value determined by the speed control device;
- power amplification of the current values obtained by means of said multiplication; 45
- sending of the amplified signals to the motor.

27. Method according to Claim 23, characterized in that it comprises an initial phase synchronization step for relative orientation of the vector representing the vectorial sum of the stator magnetic fields and the magnetic field of the rotor of the motor. 50

28. Method according to Claim 27, characterized in that said relative orientation envisages 90° phase displacement of said vectors. 55

29. Method according to Claim 28, characterized in that said phase displacement is maintained for each point along the angular trajectory of the rotor.

30. Method according to Claim 27, characterized in that said initial phase synchronization envisages the following steps:

- supplying, to the stator phases, currents such as to produce a stator field oriented at a predefined angle;
- waiting for a predefined time interval;
- setting the count to a number corresponding to a predefined angle of the stator field;
- incrementing this number by a value corresponding to a phase displacement of 90°.

31. Method according to Claim 23, characterized in that said control of the speed of the thread guide comprises the steps of:

- counting and memorizing the pulses representing the position of the thread guide;
- determining the direction of movement of the thread guide;
- comparing the count value of the existing position of the thread guide and the programmed value;
- sending torque directional signals to the device for vectorial control of the currents;
- generating a signal indicating the modulus of the torque required for the existing trajectory section;
- sending said signal indicating the modulus of the torque to the circuit for vectorial control of the currents.

32. Method according to Claim 31, characterized in that said speed control envisages an initial zero search step.

33. Method according to Claim 32, characterized in that said zero search operation envisages the following steps:

- reduction of the torque and the speed of the motor to a predefined value;
- displacement of the thread guide into a position corresponding to the absolute zero of the machine;
- resetting of the thread-guide position count;
- displacement of the thread guide into the cycle start position;
- resetting of the motor current and torque.

34. Method according to Claim 23, characterized in that it comprises error correction of the reversal point of the thread guide movement.

35. Method according to Claim 34, characterized in that said error correction envisages the following steps:

- detection and measurement of the error in the existing right-hand and left-hand speed reversal point; 5
- separate storage of said the right-hand and left-hand error;
- calculation of the respective subsequent torque reversal point; 10
- sending of the calculated reversal point to the system for comparing the existing value and the programmed value.

36. Method according to Claim 35, characterized in that said calculation of the new torque reversal point is performed on the basis of the programmed value and the error detected and stored during the previous travel movement. 15

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37. Method according to Claim 23, characterized in that it comprises positional control along the section lying between the torque reversal point and the movement reversal point.

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38. Method according to Claim 37, characterized in that said positional control envisages the following steps:

- detecting the torque reversal point; 30
- deactivating the speed control;
- activating the positional control;
- detecting the programmed position for the speed reversal point;
- detecting the existing position; 35
- calculating the difference between the two positions, i.e. the programmed position and the existing position;
- determining the torque value to be output.

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39. Method according to Claim 38, characterized in that said determination of the torque value to be output is a function of the said difference between the two positions.

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40. Method according to Claim 38, characterized in that said determination of the torque value to be output is a function of the calculated difference between the programmed speed and existing speed at the position of the said difference between the two positions. 50

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Fig. 1

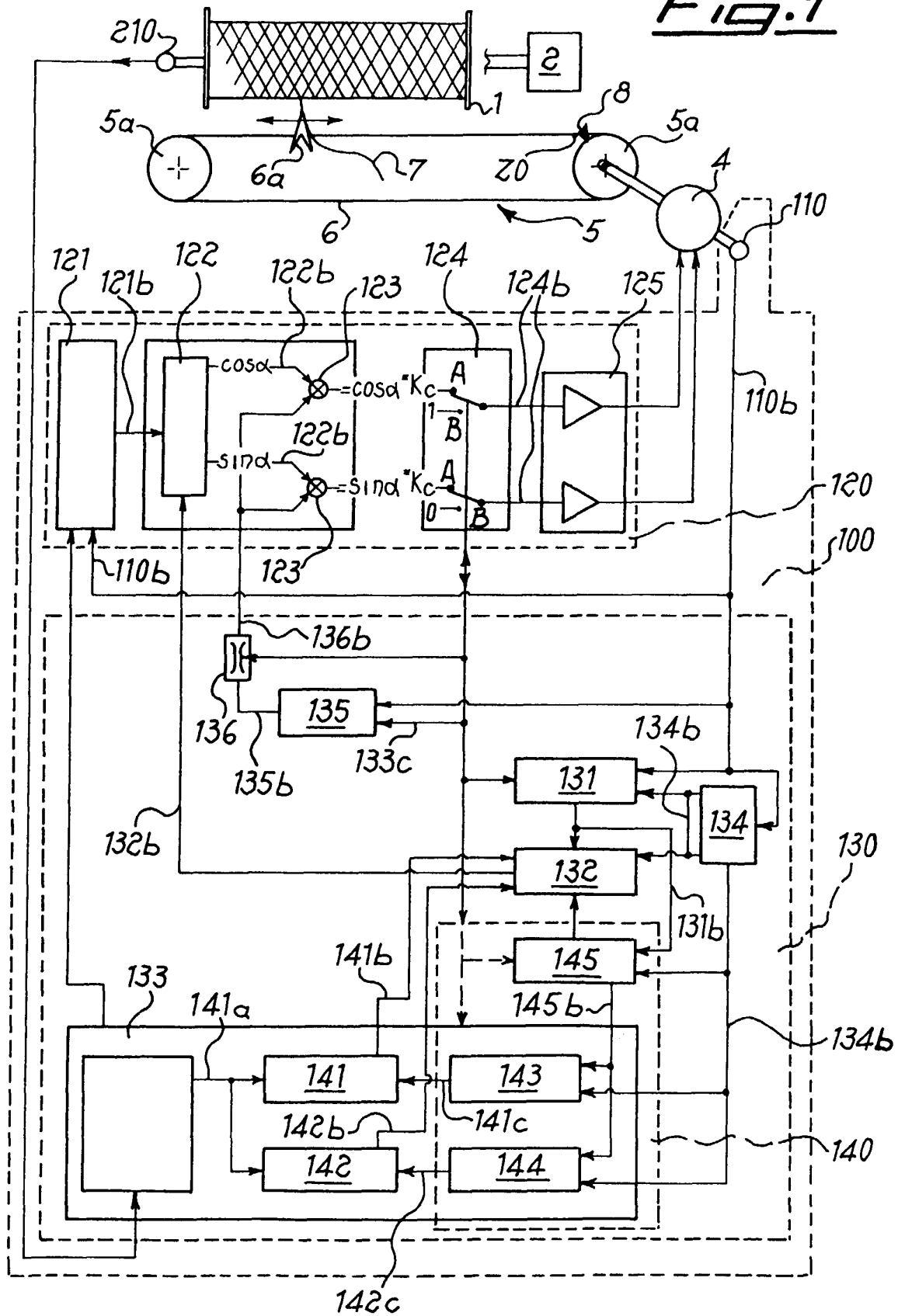


Fig. 2

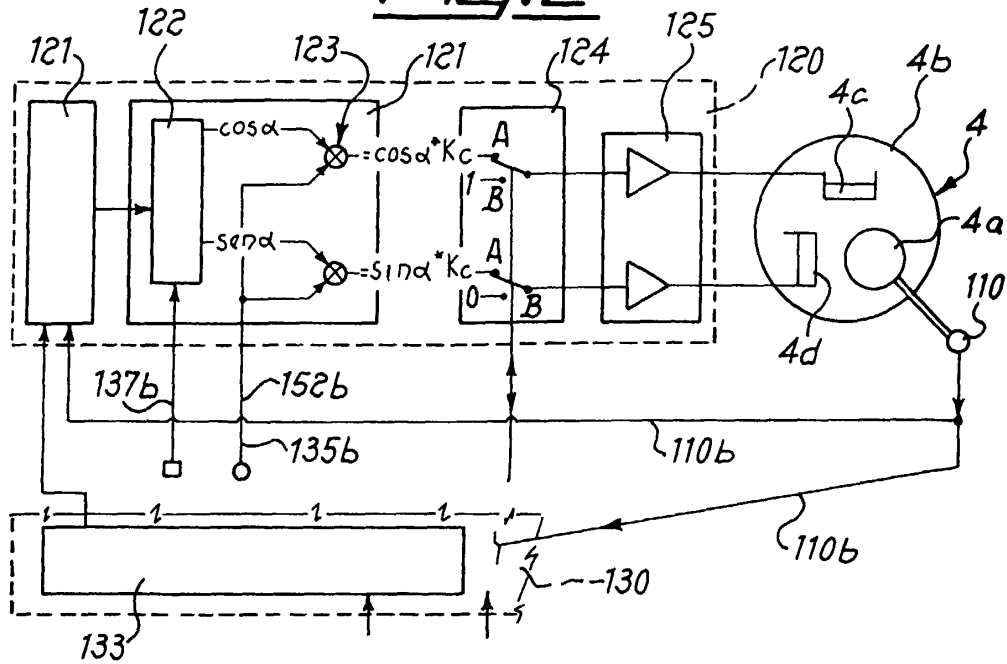


Fig. 3a

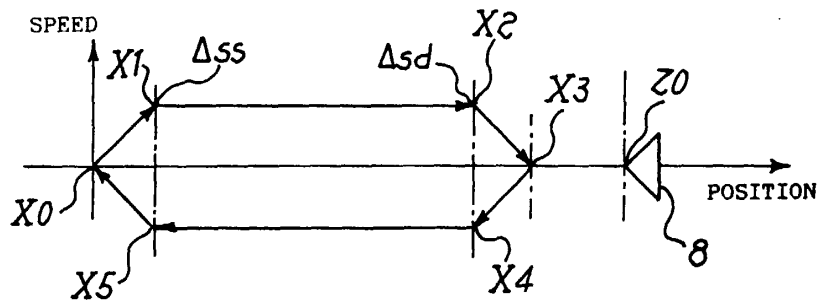


Fig. 3b

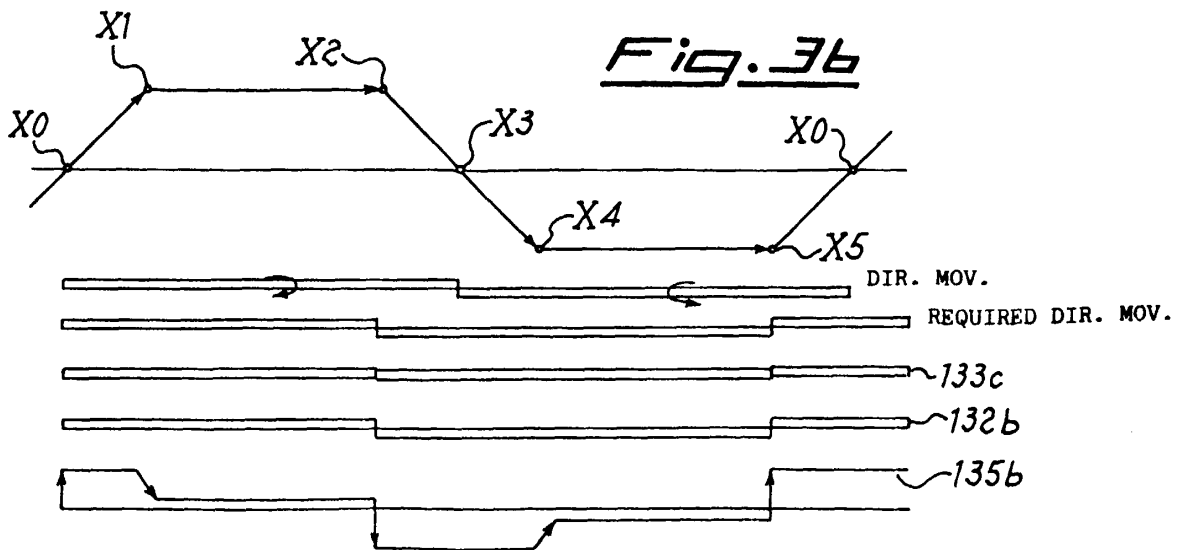


Fig. 4

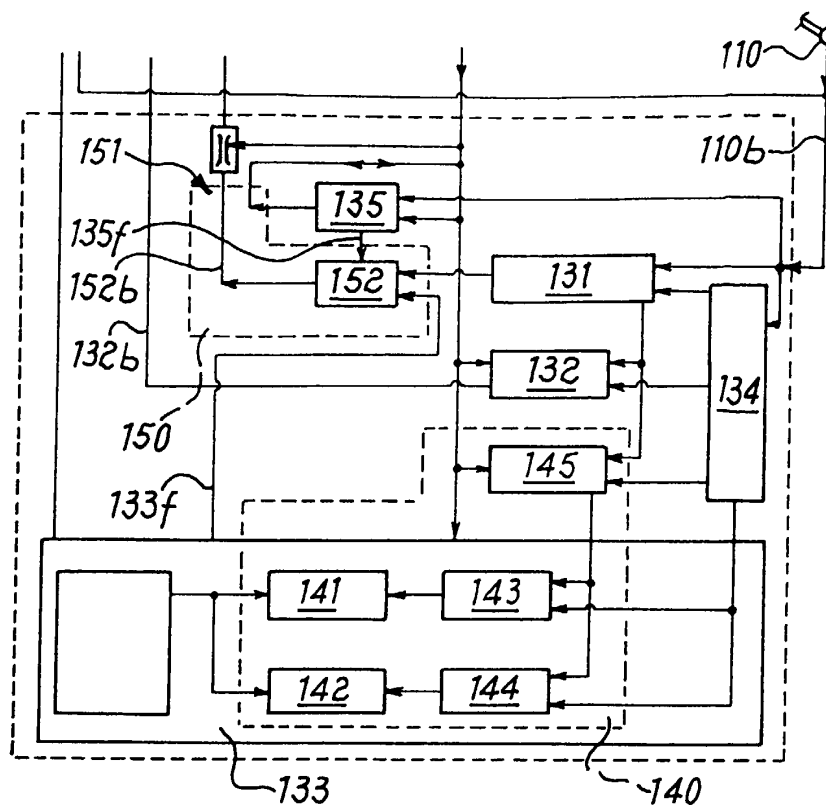


Fig. 5a

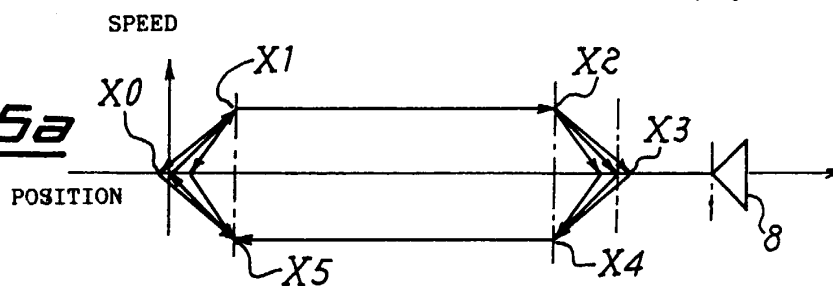


Fig. 56

