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(54) Flat knitting machine and knitting method using flat knitting machine

(57) Configuration: A flat knitting machine (2) includes at least two needle beds (4), a carriage (6) that reciprocates on the needle beds (4) and has a stitch cam motor that changes a stitch density value of a stitch cam, a carrier (8, 9) that feeds a yarn to needles of the needle beds, a yarn feeding apparatus (10) that feeds the yarn to the carrier, a sensor (27) that measures a yarn length of the yarn fed from the yarn feeding apparatus (10), and a controller (16) that controls the stitch cam motor based on a signal of the sensor (27) and corrects the stitch density value. The controller (16) corrects the stitch density value for each predetermined length that is shorter than one course in order to correct an error between a consumed yarn length and a target yarn length in a course of the carriage in which the error occurred.

Effects: An accumulated error in the stitch loop length is corrected for each course and is not carried over to the next course. Also, when yarns are connected and changed in the course, or the dyeing color of the yarn is changed, the color is changed exactly at a desired position and there is no need for treating the yarn for a margin with tuck stitches or the like.

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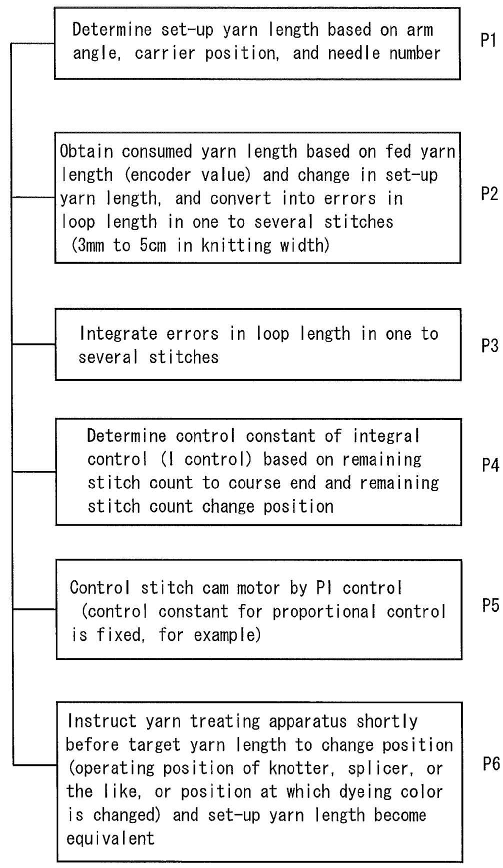

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Description

Technical Field

[0001] The present invention relates to correction of an error between a consumed yarn length and a target yarn length when knitting a knitted fabric using a flat knitting machine.

Background Art

[0002] The applicant manufactures flat knitting machines that are capable of knitting high-quality knitted fabrics by controlling the yarn length. For example, in Patent Literature 1 (JP 2952391B), a consumed yarn length is measured by a sensor, and a stitch cam motor of a carriage is controlled so that an accumulated error in the consumed yarn length in one course is eliminated in the next course. Also, a loop length routine is carried out before actually knitting a knitted fabric, and the most appropriate stitch density value is determined. In Patent Literatures 2 and 3 (JP 3603031B and JP 4016030B), a yarn feeding roller is driven by a servomotor and a yarn length to be fed is controlled.

[0003] The applicant has proposed, in addition to controlling the yarn length, to provide a flat knitting machine with a knotter, a splicer, or the like so as to connect and change yarns during knitting (Patent Literature 5: JP 2816784B). A position at which a yarn is changed needs to be located at a desired position, but it is difficult to control the yarn change position to be located exactly at the desired position. Therefore, the change position is determined so that a yarn margin is created that is shorter than one stitch, and the yarn of the margin is treated with tuck stitches or the like so as to be inconspicuous. Patent Literature 4 (JP 4366312B) focuses attention on the fact that stitch sizes vary between knitting-start/knitting-end of one course for a knitted fabric, and the intermediate portion of the course, and proposes to correct the stitch density values in the knitting-start/knitting-end.

[0004] In the control of Patent Literatures 1 to 3, one course is taken as a unit, and an error in the current course is eliminated in the next course. Therefore, the error is not eliminated within one course, thus causing variations in the stitch size. If, for example, a yarn is changed, an extra yarn for a margin is arranged since a yarn cannot be changed exactly at a desired position, and the yarn for a margin needs to be absorbed with tuck stitches or the like.

Citation List

Patent Literature

[0005]

[Patent Literature 1]	JP 2952391B
[Patent Literature 2]	JP 3603031B
[Patent Literature 3]	JP 4016030B
[Patent Literature 4]	JP 4366312B
[Patent Literature 5]	JP 2816784B

Summary of the Invention

Technical Problem

[0006] It is an object of the present invention to correct errors occurred in one course within the same course, and to enable knitting of a knitted fabric with a higher quality.

[0007] It is an additional object of the present invention to correct an accumulated error in the stitch loop length in each course, and to prevent the accumulated error from being carried over to the next course.

[0008] Furthermore, it is an additional object of the present invention, if yarns are connected and changed within a course by a knotter, a splicer, or the like or if the color of a yarn is changed within a course by a dyeing apparatus, to realize color change exactly at a desired position and to eliminate the need for treating the yarn of a margin with tuck stitches or the like.

[0009] Furthermore, it is an additional object of the present invention to prevent the stitch loop length from being drastically varied within one course.

[0010] Furthermore, it is an additional object of the present invention to prevent the stitch loop length from being varied between the start and end of one course, and the intermediate portion of the course.

Means for Solving Problem

[0011] The present invention is directed to a flat knitting machine including: at least two needle beds; a carriage that reciprocates on the needle beds and includes a stitch cam motor that changes a stitch density value of a stitch cam; a carrier that feeds a yarn to needles of the needle beds; a yarn feeding apparatus that feeds the yarn to the carrier; a sensor that measures a yarn length of the yarn fed from the yarn feeding apparatus; and a controller that controls the stitch cam motor based on a signal of the sensor and corrects the stitch density value, characterized in that the controller is configured to correct the stitch density value for each predetermined length that is shorter than one course in order to correct an error between a consumed yarn length and a target yarn length within a course of the carriage in which the error occurred.

[0012] Also, the present invention is directed to a knitting method using a flat knitting machine including: at least two needle beds; a carriage that reciprocates on the needle beds and includes a stitch cam motor that changes a stitch density value of a stitch cam; a carrier that feeds a yarn to needles of the needle beds; a yarn feeding apparatus that feeds the yarn to the carrier; a sensor that measures a yarn length of the yarn fed from the yarn feeding apparatus; and a controller that controls the stitch cam motor based on a signal of the sensor and corrects the stitch density value, the method characterized by causing the controller to perform a step for correcting the stitch density value for each predetermined length that is shorter than one course so as to correct an error between a consumed yarn length and a target yarn length within a course of the carriage in which the error occurred.

[0013] The predetermined length that is shorter than one course is, for example, a knitting width of 5 cm or less, preferably 3 cm or less, more preferably 2 cm or less, especially preferably 1 cm or less, and most preferably the length of one stitch (length of one needle). Also, the length of one course corresponds to the knitting width of a knitted fabric. Since, according to the present invention, an error between a consumed yarn length and a target yarn length is corrected in a course in which the error occurred, a knitted fabric whose stitch size hardly varies is knitted. Also, if a yarn is changed, it is possible to change the yarn at a desired position. Note that, although it is preferable that errors occurred in one course be eliminated totally in the same course, part of the errors may be carried over to the next course.

[0014] It is preferable that the controller be configured to decrease the error to a value in a tolerable range within one course of the carriage. Accordingly, even if an accumulated error occurred in one course is carried over to the next course, the value of the accumulated error remains in the tolerable range. Even if a yarn is changed at the knitting-start or the like of the next course, the yarn change position is located at a desired position of the knitted fabric since the value of the accumulated error is low.

[0015] It is preferable to include a yarn treating apparatus that changes characteristics of the yarn by connecting and changing yarns or dyeing a yarn, the controller correcting the stitch density value so that a yarn treating position in the yarn treating apparatus is located at a yarn change position on a knitted fabric. According to the present invention, since an error in the consumed yarn length is, for example, about a fraction of the yarn length of one stitch, it is possible to arrange the yarn change position with an accuracy that is higher than the size of one stitch, and to change the yarn at a target change position. No tuck stitches or the like are needed for making the excess yarn absorbed. For example, if the front surface of a knitted fabric serves as the front surface of an end product such as clothes, and the rear surface of the knitted fabric serves as the rear surface of the end product, the rear surface of the knitted fabric will be inconspicuous. And if a yarn change position is located on the rear surface of the knitted fabric, that is, on a sinker loop in the case of, for example, the plain stitches in which sinker loops are arranged at the rear, the yarn change position is inconspicuous.

[0016] It is particularly preferable that the controller be configured to correct the stitch density value based on a sum of a correction value used in proportional control for eliminating an error for each predetermined length that is shorter than one course and a correction value used in integral control for eliminating an accumulated value of the errors each occurred in the predetermined length that is shorter than one course. Note, here, that the sum encompasses not only a sum of two correction values but also a modified sum of two correction values due to the restriction such as the upper limit of the correction value for the stitch density value, and the like. In the proportional control, the error is quickly eliminated, and the stitch size is varied in a short interval. In the integral control, the elimination of the error is slow but the variations in stitch size are distributed in a longer interval. Use of both the proportional control and the integral control enables the variations in the stitch size to be unnoticeable, allowing elimination of the error within substantially one course. Accordingly, by increasing a control constant of the integral control shortly before the end of one course and shortly before the yarn change position, the accumulated error is eliminated by the end of one course, and the accumulated error is eliminated before the yarn change position.

[0017] It is preferable that the controller be configured to increase the control constant of the integral control relative to that in another area if the stitch count to the end of the course is low and if the stitch count to the yarn change position is low. With this configuration, it is possible to reduce an error that is to be carried over to the next course, and to change the yarn exactly at a desired change position on the knitted fabric. A configuration is also possible that, if the stitch count to the end of the course and the stitch count to the yarn change position are reduced to, for example, predetermined values or less, the controller increases the constant of the integral control as these counts are reduced. A configuration is also possible that, if the stitch count to the end of the course and the stitch count to the yarn change position are reduced to predetermined values or less, the controller increases the control constant of the integral control by 50%, twofold, or the like relative to that in another area of the course.

[0018] Furthermore, it is preferable that the controller include: means for obtaining, by a loop length routine performed before actually knitting a knitted fabric, a change in the consumed yarn length between a knitting-start at a start of a course and an intermediate portion of the course, and a change between a knitting-end at an end of the course and the intermediate portion of the course, and converting the obtained changes into a correction value in the knitting-start and a correction value in the knitting-end; and means for correcting, when actually knitting the knitted fabric, a stitch density value with respect to the knitting-start based on a sum of the correction value in the knitting-start and a stitch density correction value for correcting an error between the consumed yarn length and a target yarn length, and correcting a stitch density value with respect to the knitting-end based on a sum of the correction value in the knitting-end and a stitch density correction value for correcting an error between the consumed yarn length and a target yarn length.

[0019] With this, it is possible to exactly correct errors in the knitting-start and the knitting-end. Note, here, that the sum encompasses not only a sum of two correction values but also a modified sum of two correction values due to the restriction such as the upper limit of the correction value for the stitch density value, and the like. The correction values in the knitting-start and the knitting-end obtained by the loop length routine may be used during actual knitting of a knitted fabric without being modified, or may be modified, during actual knitting of the knitted fabric, based on a moving average or the like of errors in the knitting-starts and a moving average or the like of errors in the knitting-ends for a plurality of courses. The means for converting the obtained changes into a correction value in the knitting-start and a correction value in the knitting-end corresponds to an auxiliary data memory and a CPU according to the embodiment, and the means for correcting stitch density values based on sums corresponds to the CPU according to the embodiment.

Brief Description of the Drawings

[0020]

FIG. 1 is a front view illustrating a flat knitting machine according to an embodiment.
FIG. 2 is a diagram illustrating a yarn feeding apparatus and a yarn treating apparatus according to the embodiment.
FIG. 3 is a block diagram illustrating a control system of the flat knitting machine according to the embodiment.
FIG. 4 is a flowchart illustrating a loop length routine according to the embodiment.
FIG. 5 is a diagram illustrating processes according to the embodiment.
FIG. 6 is a diagram illustrating control of errors in the loop length according to the embodiment.
FIG. 7 is a diagram schematically illustrating a knitted fabric according to the embodiment.

Description of Embodiment

[0021] Hereinafter, the best mode for implementing the invention will be described.

Embodiment

[0022] FIGS. 1 to 7 show a flat knitting machine 2 and a knitting method according to an embodiment. In the drawings, the flat knitting machine denoted by the reference numeral 2 is provided with, for example, two or four needle beds 4. A carriage 6 reciprocates on the needle beds 4 and operates the needles of the needle beds 4. A yarn 18 is fed to the needles from carriers 8 and 9. The operation of the needles caused by the carriage 6 refers to selecting needles for knit/tuck/miss stitches, or the like and to guiding the needles selected for knit and tuck stitches and the needles for performing transfer using a built-in cam system. The cam system includes a cam, called a stitch cam, and a stitch cam motor for causing the stitch cam to slide. By changing the position (stitch density value) of the stitch cam, the length by which the needles are drawn (the length by which the needles are retracted on the needle bed side) is changed. The stitch loop length is changed in this way. The stitch density value shows a positive value when the stitch cam is lowered to make stitches larger, and the stitch density value shows a negative value when the stitch cam is raised to make stitches smaller.

[0023] The carriage 6 carries the carriers 8 and 9, and a sensor (not shown) detects the position (needle number) of the carriage 6 with respect to the needle bed 4. Also, a stitch row that the carriage 6 creates with one stroke is defined as stitches for one course. The length of one course corresponds to the knitting width of a knitted fabric. Note that the carriers 8 and 9 may be self-propelled instead of being carried by the carriage 6.

[0024] The reference numeral 10 denotes a yarn feeding apparatus, and the yarn feeding apparatus feeds the carriers 8 and 9 with yarns 18 and 19. The reference numeral 12 denotes a yarn treating apparatus, which is, for example, an apparatus that connects and changes the yarns, such as a knotter or a splicer, or an apparatus that dyes the yarn, such as an ink-jet printer. A position at which the yarn is changed and a position at which the color of the yarn is changed by changing the dyeing color are collectively referred to as change positions. The flat knitting machine 2 according to the embodiment knits a knitted fabric having color patterns with the use of a few carriers 8 and 9 by changing the yarn. The flat knitting machine 2 obtains a knitted fabric that is not voluminous and is easy to wear, since the knitted fabric has, on its rear side, less number of yarns than that obtained by a color jacquard knitted fabric. Furthermore, the operations of the carriers 8 and 9 are simplified as compared with the case where an intarsia knitting is used, and the flat knitting machine 2 does not need a mechanism for stopping the carriers 8 and 9 exactly at predetermined positions.

[0025] The reference numeral 14 denotes a cone of the yarn, which may be a yarn cheese, or the like and serves as a supply source of the yarn. The yarn treating apparatus 12 is disposed between the cone 14 (supply source of the yarn) and the yarn feeding apparatus 10. The flat knitting machine 2, which includes the yarn feeding apparatus 10 and the yarn treating apparatus 12, is controlled by a controller 16.

[0026] FIG. 2 shows the yarn feeding apparatus 10 in detail. The reference numeral 20 denotes a servomotor, and the servomotor drives a driving roller 22, and feeds the yarn 18 or the like between the driving roller 22 and a driven roller 24 to the carriers 8, 9, and the like via a guide roller 25 and a flexible arm 26. The rotation speeds of the servomotor 20, the driven roller 24, and the like are monitored by, for example, an encoder 27, and the yarn length of the yarn fed from the driving roller 22 is obtained. The arm 26 is a buffer for the yarn 18 or the like, the angle of the arm 26 is detected by an angle sensor 28, and the detected angle is converted into the yarn length of the yarn accumulated by the arm 26. Note that, instead of being actively fed by the servomotor 20, the yarn 18 or the like may be unwound from the cone 14 with a tension, and the rotation speed of the driven roller 24 may be monitored by the encoder. The arm 26 may change to serve as a buffer of any yarn.

[0027] The yarn treating apparatus 12 is a knotter, a splicer, or the like that connects and changes the yarns 18 and 19 at, for example, a treating position 30, or may be an ink-jet printer or the like. The purpose of connecting and changing the yarns is primary to change the color of the knitted fabric, and the yarns may be connected and changed when the remaining amount of the cone 14 is reduced. Also, the color of the yarn 18 or the like is changed by changing a dye to be sprayed using the ink-jet printer or its density. A position at which the yarns are connected and changed or the dyeing color is changed is referred to as a yarn treating position 30. The yarn length between the treating position 30 and the driving roller 22 is already known for the controller 16.

[0028] FIG. 3 shows a configuration of the controller 16, in which signals indicating an encoder value S1, an arm angle S2, a position S3 of the operating carrier, a needle number S4 of a needle operated by the carriage 6, a carriage running direction and speed S5, and the like are input into an input interface 31. Since the carriage 6 operates a plurality of needles at the same time, the needle number is assumed to be, for example, a needle number of a needle that has entered into the stitch cam shortly before, a needle number of a needle that has been selected shortly before, or the like. Since a stitch loop length varies depending on whether or not the carriage running direction is equivalent to a direction in which the yarn 18 or the like is fed (whether the yarn is fed from the left side or the right side of FIG. 1), the stitch density value is corrected based on the running direction and speed. If the yarn is fed from the upper part to the lower part of FIG. 1, the direction in which the yarn is fed and the running direction of the carriage 6 cross at a right angle, hardly affecting each other, and thus correction based on the running direction and speed of the carriage 6 may be omitted.

[0029] A knitting data memory 32 has stored therein needle operation lines for knitting a knitted fabric, a stroke of the carriage 6, and the like, and it is clear from the needle operation lines what kind of stitches and how many stitches are knitted, how many stitches are present by the end of the course, and the like. A target loop length memory 33 has stored therein target values of the loop lengths of one stitch for each knitting type (combinations of types of stitches, such as knit/tuck/miss, and types of knitting structures, such as the plain stitches, the rib stitches, or the jacquard stitches). In the case of miss stitches, a yarn runs only on the rear surface of a knitted fabric, but the yarn running on the rear surface is regarded as miss stitches and the stitch loop lengths for the miss stitches are stored in the target loop length memory 33. If the same stitch density values are used in the start (knitting-start) and the end (knitting-end) of one course, the stitch loop length varies between the knitting-start/knitting-end and the intermediate portion of the one course. An auxiliary data memory 34 has stored therein correction stitch density values for the knitting-start and the knitting-end.

[0030] A CPU 36 performs, based on signals from the input interface 31, knitting data, target loop lengths, and correction values for the knitting-start and the knitting-end, the following processing of:

- Obtaining an error in the loop length for each stitch, or errors in the loop lengths in a range of a knitting width of 5 cm or less, and storing the obtained errors in an error memory 37. According to the embodiment, a range in which an error is obtained is each needle, that is, each stitch. However, it is also possible to obtain a sum of errors in the loop length in a range of a knitting width of, for example, 5 cm or less, preferably 3 cm or less, more preferably 2 cm or less, further preferably 1 cm or less.
- Obtaining an accumulated value of the errors in the loop length obtained in the above-described manner, and storing the obtained accumulated value in an accumulated error memory 38.
- Obtaining a set-up yarn length, that is, a yarn length between the yarn treating position 30 and the needles, and storing the obtained set-up yarn length in a set-up yarn length memory 39. The set-up yarn length is a sum of a yarn length between the yarn treating position 30 and the driving roller 22, the yarn length accumulated at the arm 26, a yarn length between the driving roller 22 and the carrier 8 etc., and a yarn length between the carrier 8 etc. and the needles. The yarn length between the yarn treating position 30 and the driving roller 22 is fixed, and the yarn length between the driving roller 22 and the carrier 8 etc. depends on the angle of the arm 26 and the position of the carrier 8 etc. Therefore, it is not necessary to obtain the set-up yarn length itself, and instead, for example, the length calculated by subtracting the yarn length between the yarn treating position 30 and the driving roller 22 from the set-up yarn length may be obtained.
- Obtaining a target yarn length between the yarn treating position and the change position based on the knitting data and target values of the loop lengths

for each type of stitches, and storing the obtained target yarn length in a memory 40 for storing the target yarn length to the change position. The type of stitches until the change position, knitting to which stitches belong, such as the plain stitches or the rib stitches, and the stitch count are known from the knitting data, and thus it is possible to obtain, by integrating the target values of the loop lengths for the stitches, the target yarn length between the yarn treating position and the change position.

- Obtaining a remaining stitch count from the current knitting position to the end of the course, and a remaining stitch count from the current knitting position to the yarn change position based on the knitting data and the currently operating needle number, and storing the obtained remaining stitch counts in a memory 41 for storing remaining stitch counts to the end of the course and to the change position.
- Increasing, if the stitch count to the end of the course or the stitch count to the change position is reduced, a control constant of the integral control for the stitch cam motor as compared with that in another area at, for example, a predetermined rate, or increasing the remaining stitch count in multiple stages as it is reduced.
- Changing the stitch density values for the knitting-start and the knitting-end, based on the correction values stored in the auxiliary data memory 34. Note that the stitch density value is controlled as a target value of the rotating angle of the shaft of the stitch cam motor. The widths of the knitting-start and the knitting-end correspond to about several needles, that is, knitting widths of 5 cm or less, for example.
- Performing, on the stitch cam motor, not only correction in the knitting-start and the knitting-end but also the proportional control for eliminating an error in the loop length for one stitch to stitches in a predetermined knitting width of 5 cm or less, and the integral control for eliminating the accumulated value of the errors.
- Instructing the yarn treating apparatus 12 to change the yarn, the dyeing color, or the like shortly before the set-up yarn length and the target yarn length to the change position become equivalent to each other. Instructing "shortly before" means instructing earlier by the time period corresponding to a possible delay for the start of the yarn treatment after the instruction is given.

[0031] The output interface 42 outputs instructions to a stitch cam motor (not shown) and the yarn treating apparatus 12. If, for example, the output interface 42 instructs the servomotor 20 of the yarn feeding apparatus 10 to feed a yarn for target loop lengths, the servomotor 20 will also be controlled. The servomotor 20 is controlled by a signal of the angle sensor 28 if the angle of the arm 26 is fixed and the tension on the yarn is controlled so as to be constant.

[0032] In addition, a LAN interface 43 and a USB drive 44 are provided, and knitting data is accepted from the LAN, or by separating the yarn treating apparatus 12 from the flat knitting machine 2, the yarn treating apparatus 12 may be instructed via the LAN. Alternatively, knitting data may be accepted from the USB memory 44.

[0033] The target loop lengths of stitches may be designated together with the knitting data, or may be determined by the loop length routine shown in FIG. 4 using the flat knitting machine 2. A knitted fabric is knitted while changing the stitch density values in multiple levels in which several courses are knitted for each stitch density value (Step 1). A user selects the most appropriate stitch density value by evaluating the knitted fabric, and designates the stitch loop length at that time as the target loop length (Step 2). Also, changes in the actual loop length in the knitting-start and the knitting-end with respect to the loop length in the intermediate portion of the course are monitored using a signal or the like from the encoder 27 of the servomotor 20, and correction values for the knitting-start and the knitting-end are determined in order to eliminate this differences (Step 3). Since the knitting widths in the knitting-start and the knitting-end that are needed to be corrected also become clear by the loop length routine, it is possible to automatically determine the knitting widths in the knitting-start and the knitting-end for which correction is to be performed.

[0034] FIG. 5 shows processes for controlling the stitch loop length (control of the stitch cam motor) and for controlling the yarn treating apparatus 12 according to the embodiment. In a set-up yarn length determination process P1, a set-up yarn length is obtained based on the angle of the arm 26, the positions of the carriers 8, 9, and the like, the needle numbers, and the like, and the obtained set-up yarn length is stored in a set-up yarn length memory 39. In a loop length error calculation process P2, a consumed yarn length (actual loop length) for each stitch is obtained based on the length of the fed yarn that was obtained by the encoder 27, and a change in the set-up yarn length. Note that the difference between the actual loop length and the target loop length for each stitch is the error for each stitch. Using, as the error in the loop length, the error for each stitch (an error in the loop length for each needle) or an average error in the loop lengths in a range corresponding to about several needles, the following control is performed. The average error in the loop lengths refers to an average of errors in a range of a knitting width of, for example, 5 cm or less, preferably 3 cm or less, more preferably 2 cm or less, particularly preferably 1 cm or less. In the embodiment, a flat knitting machine with 8 mm knitting width for each needle is used, and an error in the loop length for each needle is obtained.

[0035] In an accumulated error calculation process P3, an accumulated value of the errors in the loop lengths is obtained. In an integral control constant determination process P4, a control constant of the integral control of PI control (proportional and integral control) for the stitch density value is changed based on the remaining stitch count to the end of the course, and the remaining stitch count to the yarn change position. If the remaining stitch count is reduced, the control constant is increased, and if the remaining stitch count is increased, the control constant is reduced so as to return to the normal value. The end of the course is the end of the knitted fabric, and the stitches are inconspicuous there. Furthermore, in the case of shaping knitting, in which parts are knitted according to the shape of the clothes, and then the parts are stitched up together by linking, the stitching up is performed at the end of the course, and the stitched-up portion is inconspicuous even if the size of the stitches are not uniform. By reducing the accumulated value of the errors at a change position at which the yarn treatment is performed, the change position is arranged at an inconspicuous position of a sinker loop or the like on the rear surface of the knitted fabric. Note that, if needle loops are present on the rear surface of the knitted fabric, the yarn is changed at a needle loop. Accordingly, it is necessary to reduce the accumulated value of errors at a change position, and the same applies to the case where the yarn is changed at the end of the course. Therefore, if the remaining stitch count to the end of the course and the remaining stitch count to the yarn change position are reduced, the control constant is increased.

[0036] In a PI control process P5, the stitch cam motor is controlled by PI control, the PI control referring to a combination of:

- Proportional control for eliminating an error in the loop length for one stitch to stitches in a knitting width of 5 cm or less, or the like; and
- Integral control for eliminating an accumulated error in the loop length, the combination also including:
- Correction values in knitting-start/knitting-end. In a yarn treatment control process P6, the yarn treating apparatus 12 is instructed to change the yarn, the dyeing color, or the like earlier than the time when the set-up yarn length and the target yarn length to the change position become equivalent to each other, by the time period corresponding to a possible delay for the start of the yarn treatment after the instruction is given.

[0037] The processes P1 to P3, and P5 are performed, for example, for each needle, that is, each stitch, or may be performed for each predetermined knitting width of 5 cm or less, 3 cm or less, 2 cm or less, 1 cm or less, or the like. Also, the process P4 is performed when the needle approaches the end of the course and the change position, and the process P6 starts when the set-up yarn length approaches the target yarn length to the change position.

[0038] Although FIG. 6 shows control of the loop length for each needle, the control may be performed, as described above, for a predetermined knitting width of 5 cm or less, 3 cm or less, 2 cm or less, 1 cm or less or the like. The vertical axis indicates an accumulated error, and the horizontal axis schematically indicates needle numbers. Dead zones are provided for feedback control of an accumulated error and for feedback control of errors for respective needles, and in the dead zones, no stitch density value is changed for the errors. The solid line indicates control excluding those shortly before the end of the course and shortly before the yarn change position, and the dashed line indicates controls shortly before the end of the course and shortly before the yarn change position. These lines differ from each other in values of the control constant of the integral control.

[0039] If an error that exceeds the dead zone occurs at the needle number 4, the stitch cam motor is controlled by changing the stitch density value using the integral control, and adding changes in the stitch density value using the proportional control. The reason why the integral control is also used is that, only with the proportional control, the stitch density value for the error is changed abruptly and non-uniformity in the stitch sizes is noticeable. In the control indicated by the solid line, the accumulated error continues to increase until the needle number 6, and then the accumulated error slowly decreases to return to the dead zone at the needle number 10. In this period, the loop length of a stitch is smaller than the target value at the needle numbers 7, 8, and 9, and thus the proportional control suppresses the integral control from eliminating the accumulated error, resulting in control in which variations in stitch size are less noticeable, as a whole, than in the case of simple integral control.

[0040] Shortly before the end of the course and shortly before the yarn change position, the control constant of the integral control is increased so that the accumulated error is not carried over to the next course and the accumulated error becomes 0 at the change position. The results obtained when the control constant of the integral control is increased are indicated by the dashed line. The accumulated error detected at the needle number 4 is quickly treated to return to the dead zone at, for example, the needle number 8.

[0041] FIG. 7 schematically shows a knitted fabric 70 to be knitted. The reference numerals 71, 73, and 76 denote areas knitted by the same yarn, and the reference numerals 74 and 75 denote two types of areas knitted by another yarn. Change lines 77 and 78 at which the yarn is changed are created along the border of the areas, as shown in the lower part of the drawing, and a change point 79 at which the yarn is changed is created at the end of the course, as shown in the left part of the drawing.

[0042] By positioning the changed yarn exactly at a predetermined position, such as the change lines 77, 78, and the change point 79, the changed position of the yarn is made inconspicuous, enabling realization of the designed color patterns. In order to do so, the error from the target value on the knitting data at the yarn change position is reduced to a value that is shorter than one stitch loop, so that the change is performed at, for example, a sinker loop on the inconspicuous rear surface of the knitted fabric. With this measure, it is not necessary to treat excess stitches with tuck stitches or the like.

[0043] Regarding the knitting-start/knitting-end, correction is performed in the case of a plain knitted fabric such that the stitch density value is increased in the knitting-start, and the stitch density value is decreased in the knitting-end. Also, in the case of tubular knitting, correction is performed such that the stitch density value is decreased in knitting-start, and the stitch density value is increased in knitting-end.

[0044] The embodiment achieves the following effects:

1) The stitch loop length is caused to approach a target value by correcting a stitch density value, for example, for each needle in one course. Specifically, the accumulated error is prevented from being carried over to the next course.
2) The yarn change position is located at an inconspicuous position by increasing a control constant of integral control shortly before the yarn change position.
3) Since a control constant of integral control is increased shortly before the end of the course at which variations in the size of the stitches are not noticeable, the accumulated error is eliminated without making the variations in the size of stitches noticeable.
4) By using both integral control and proportional control, a stitch density value is prevented from being changed abruptly.
5) With these measures, a knitted fabric having color patterns is realized in a manner different by intarsia knitting or jacquard.
6) By correcting errors in the knitting-start and the knitting-end, the stitch size is prevented from being varied at the end of the knitted fabric.
7) The knitting widths in the knitting-start and the knitting-end for which correction is to be performed are automatically determined by the loop length routine.

[0045] It should be noted that the control according to the embodiment does not need to be implemented with respect to the entire knitted fabric. For example, in areas in which the yarn is not changed, such as the areas 71 and 76 of FIG. 7, the stitch density value may be corrected so that the accumulated error in the current course is eliminated in the next course.

List of Reference Numerals

[0046]

2	Flat knitting machine
4	Needle bed
6	Carriage
8, 9	Carrier
10	yarn feeding apparatus
12	Yarn treating apparatus
14	Cone
16	Controller
18, 19	Yarn
20	Servomotor
22	Driving roller
24	Driven roller
25	Guide roller
26	Arm
27	Encoder
28	Angle sensor
30	Treating position
31	Input interface
32	Knitting data memory
33	Target loop length memory
34	Auxiliary data memory
36	CPU
37	Error memory
38	Accumulated error memory
39	Set-up yarn length memory
40	Memory for storing target yarn length to change position
41	Memory for storing remaining stitch count to course end and change position
42	Output interface
43	LAN interface
44	USB drive
70	Knitted fabric
71 to 76	Area
77, 78	Change line
79	Change point

P1	Set-up yarn length determination process
P2	Loop length error calculation process
P3	Accumulated error calculation process
P4	Integral control constant determination process
P5	PI control process
P6	Yarn treatment control process

Claims

1. A flat knitting machine (2) comprising: at least two needle beds (4); a carriage (6) that reciprocates on the needle beds (4) and includes a stitch cam motor that changes a stitch density value of a stitch cam; a carrier (8, 9) that feeds a yarn to needles of the needle beds (4); a yarn feeding apparatus (10) that feeds the yarn to the carrier (8, 9); a sensor (27) that measures a yarn length of the yarn fed from the yarn feeding apparatus (10); and a controller (16) that controls the stitch cam motor based on a signal of the sensor (27), and corrects the stitch density value, **characterized in that** the controller (16) is configured to correct the stitch density value for each predetermined length that is shorter than one course in order to correct an error between a consumed yarn length and a target yarn length within a course of the

carriage (6) in which the error occurred.

2. The flat knitting machine (2) according to claim 1, **characterized in that** the controller (16) is configured to decrease the error to a value in a tolerable range within one course of the carriage (6).

3. The flat knitting machine (2) according to claim 1 or 2, **characterized by** comprising a yarn treating apparatus (12) that changes characteristics of the yarn by connecting and changing yarns or dyeing a yarn, and in that the controller (16) corrects the stitch density value so that a yarn treating position in the yarn treating apparatus (12) is located at a yarn change position on a knitted fabric.

4. The flat knitting machine (2) according to any one of claims 1 to 3, **characterized in that** the controller (16) is configured to correct the stitch density value based on a sum of a correction value used in proportional control for eliminating an error for each predetermined length that is shorter than one course, and a correction value used in integral control for eliminating an accumulated value of the errors each occurred in the predetermined length that is shorter than one course.

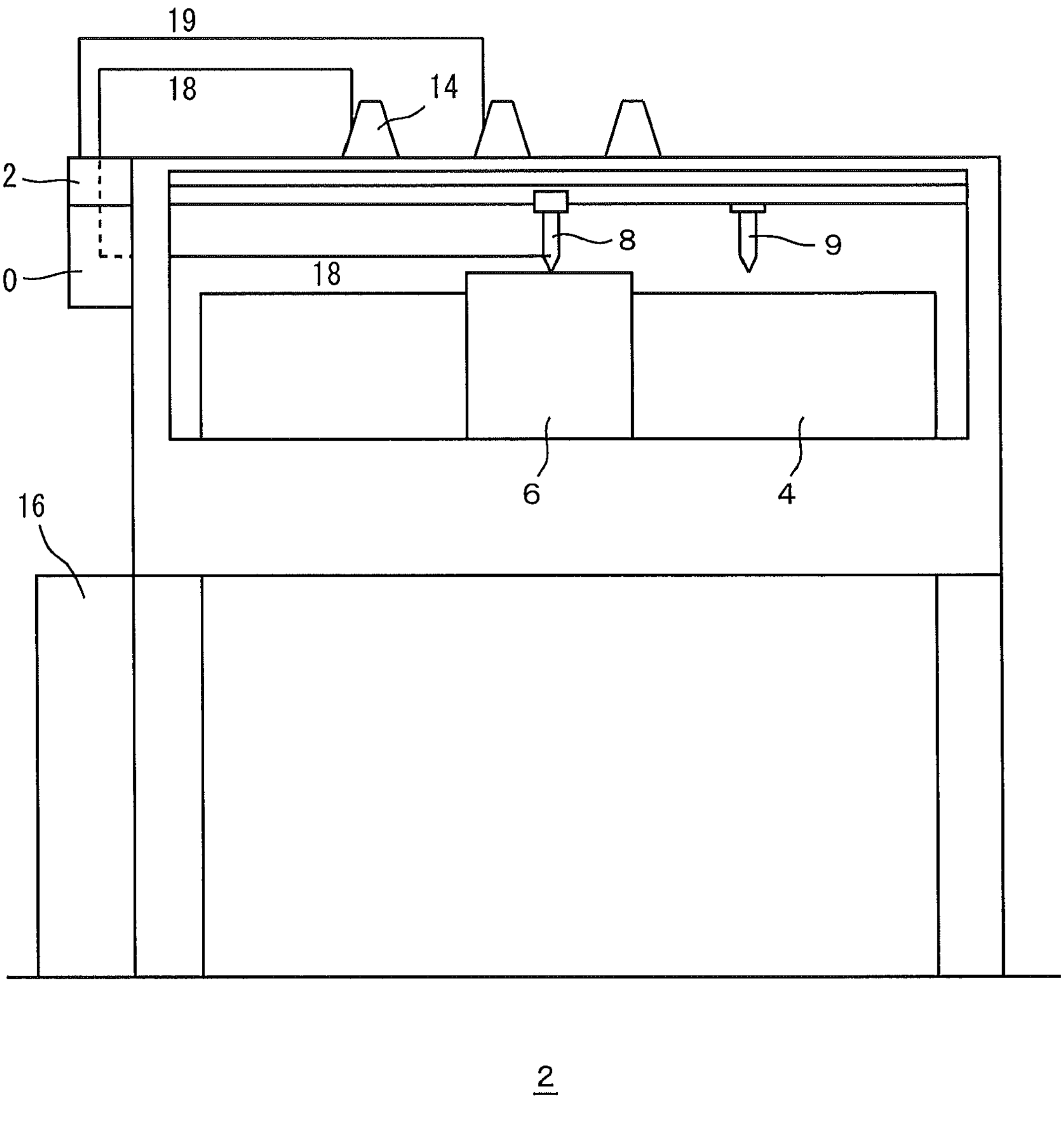
5. The flat knitting machine (2) according to claim 4, **characterized in that** the controller (16) is configured to increase a control constant of the integral control relative to that in another area if the stitch count to the end of the course is low and if the stitch count to the yarn change position is low.

6. The flat knitting machine (2) according to any one of claims 1 to 5, **characterized in that** the controller (16) includes:

means for obtaining, by a loop length routine performed before actually knitting a knitted fabric, a change in the consumed yarn length between a knitting-start at a start of a course and an intermediate portion of the course, and a change between a knitting-end at an end of the course and the intermediate portion of the course, and converting the obtained changes into a correction value in the knitting-start and a correction value in the knitting-end; and
means for correcting, when actually knitting the knitted fabric, a stitch density value with respect to the knitting-start based on a sum of the correction value in the knitting-start and a stitch density correction value for correcting an error between the consumed yarn length and a target yarn length, and correcting a stitch density value with respect to the knitting-end based on a sum of the correction value in the knitting-end and a stitch density correction value for correcting an error between the consumed yarn length and a target yarn length.

7. A knitting method using a flat knitting machine (2) including: at least two needle beds (4); a carriage (6) that reciprocates on the needle beds (4) and includes a stitch cam motor that changes a stitch density value of a stitch cam; a carrier (8, 9) that feeds a yarn to needles of the needle beds (4); a yarn feeding apparatus (10) that feeds the yarn to the carrier (8, 9); a sensor (27) that measures a yarn length of the yarn fed from the yarn feeding apparatus (10); and a controller (16) that controls the stitch cam motor based on a signal of the sensor (27), and corrects the stitch density value,
the method **characterized by** causing the controller (16) to perform a step for correcting the stitch density value for each predetermined length that is shorter than one course so as to correct an error between a consumed yarn length and a target yarn length within a course of the carriage (6) in which the error occurred.

F I G. 1



F I G. 2

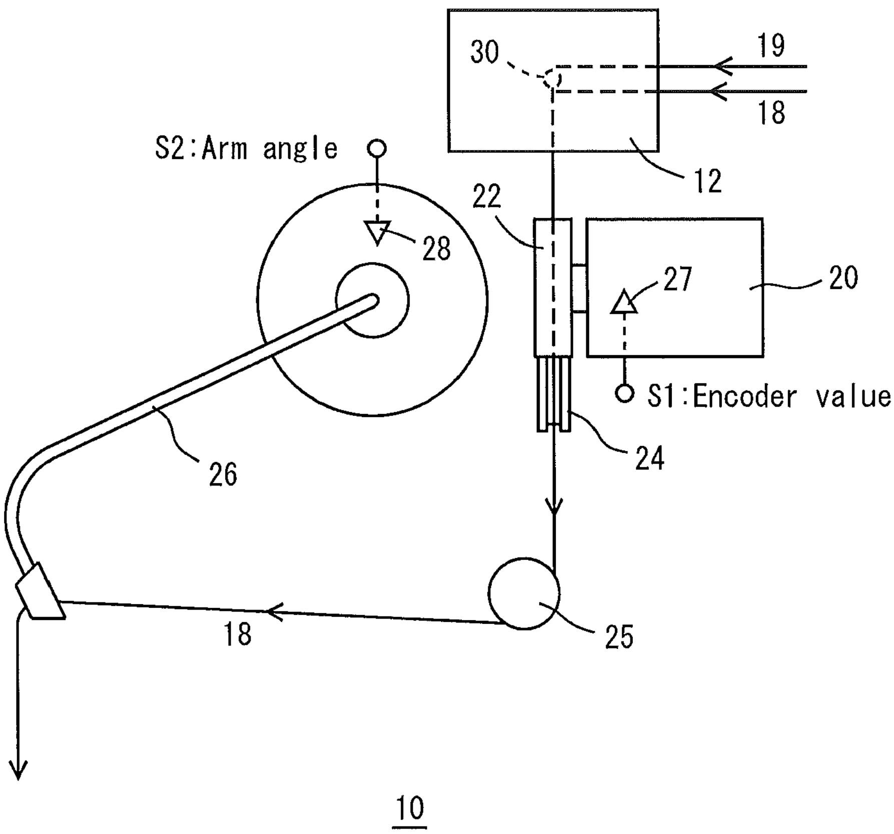

30
19
18
12
S2:Arm angle
22
28
27
20
S1:Encoder value
24
26
25
18
10

FIG. 3

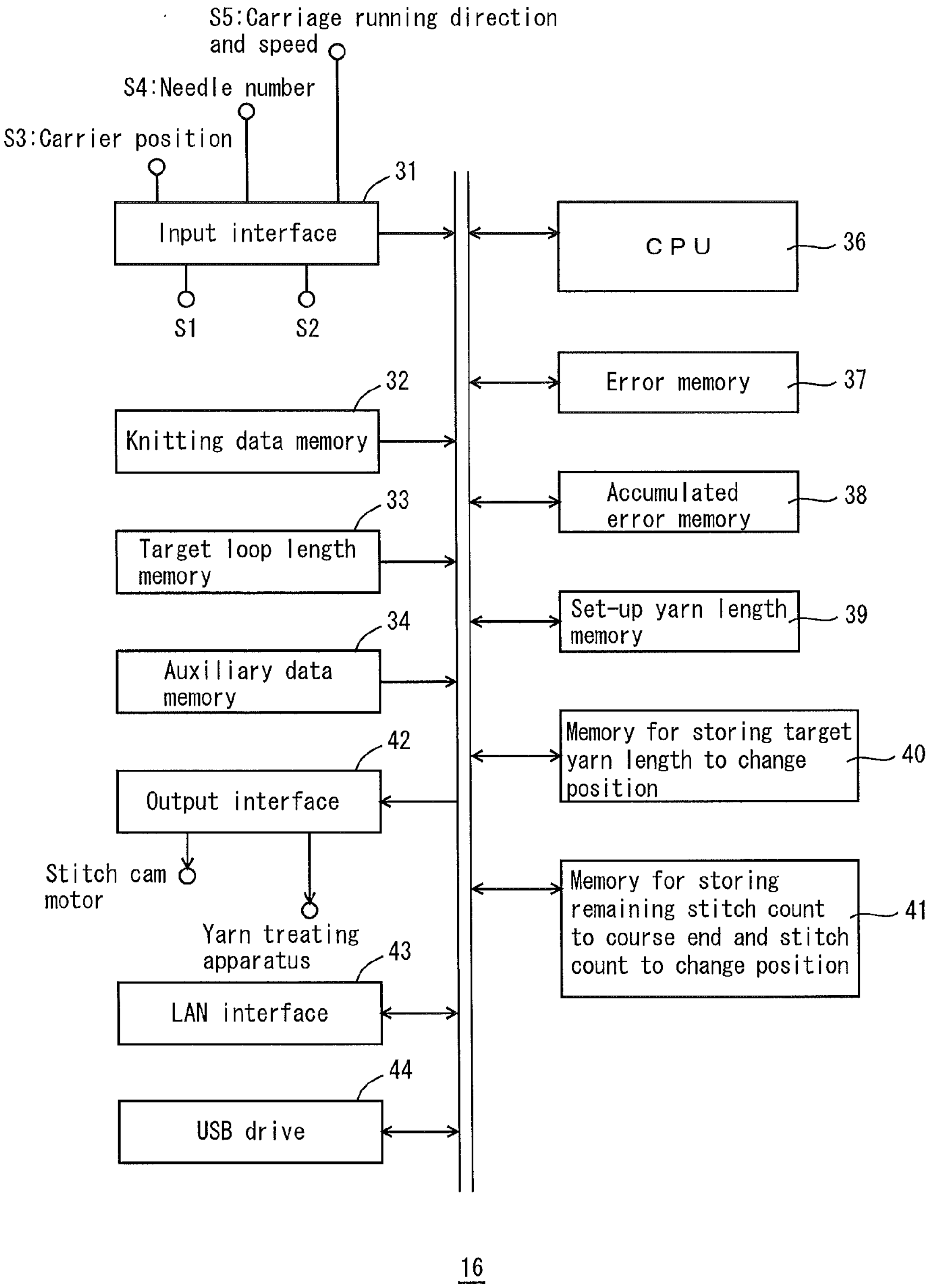

S5:Carriage running direction and speed
S4:Needle number
S3:Carrier position
31
Input interface
S1
S2
CPU
36
32
Knitting data memory
Error memory
37
33
Target loop length memory
Accumulated error memory
38
34
Auxiliary data memory
Set-up yarn length memory
39
42
Output interface
Memory for storing target yarn length to change position
40
Stitch cam motor
Yarn treating apparatus
Memory for storing remaining stitch count to course end and stitch count to change position
41
43
LAN interface
44
USB drive
16

FIG. 4

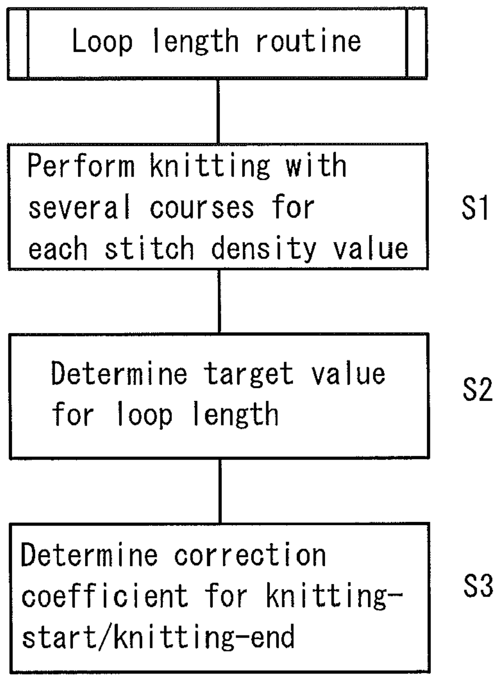

Loop length routine
Perform knitting with several courses for each stitch density value
S1
Determine target value for loop length
S2
Determine correction coefficient for knitting-start/knitting-end
S3

FIG. 5

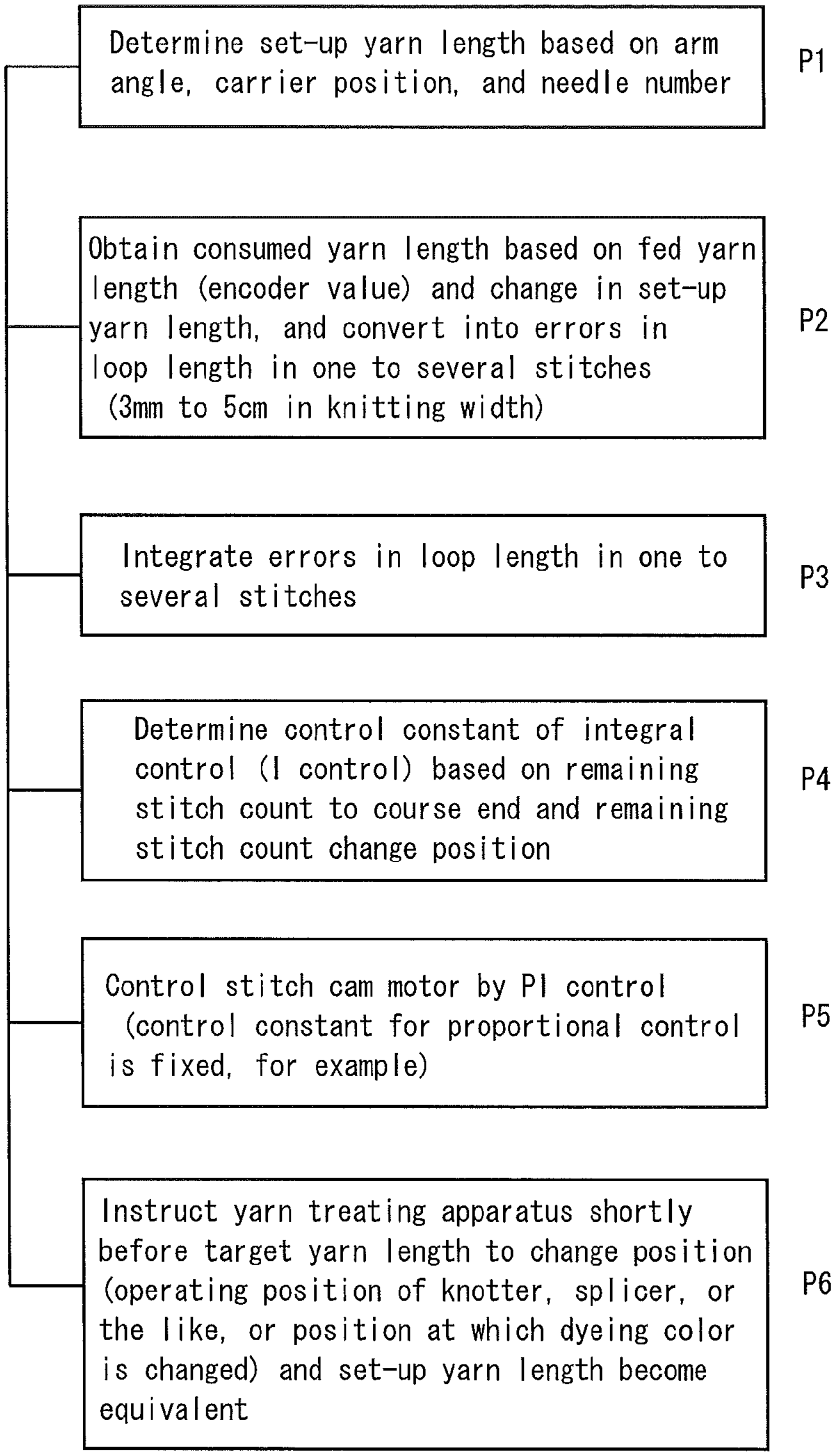
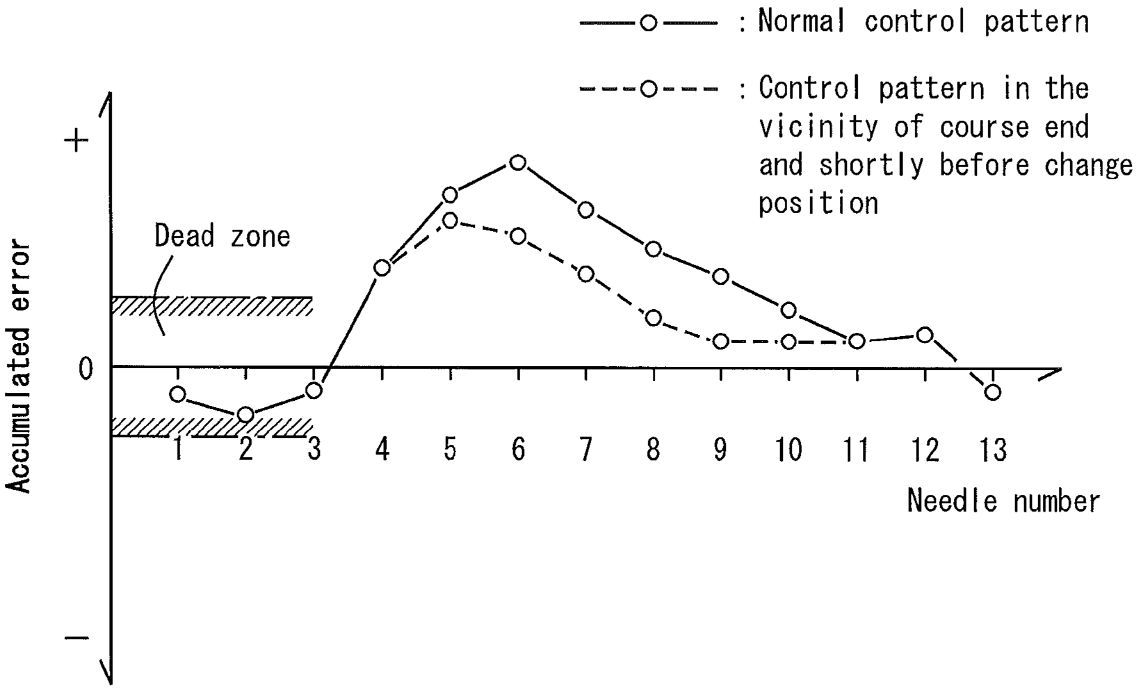
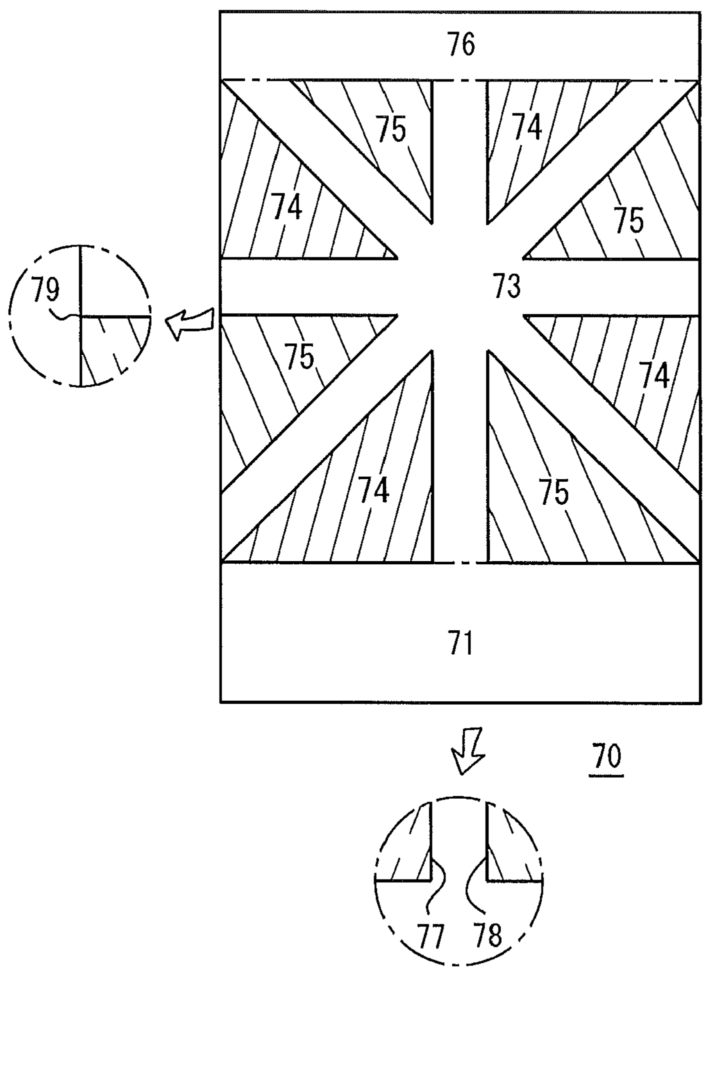

Determine set-up yarn length based on arm angle, carrier position, and needle number
P1
Obtain consumed yarn length based on fed yarn length (encoder value) and change in set-up yarn length, and convert into errors in loop length in one to several stitches (3mm to 5cm in knitting width)
P2
Integrate errors in loop length in one to several stitches
P3
Determine control constant of integral control (I control) based on remaining stitch count to course end and remaining stitch count change position
P4
Control stitch cam motor by PI control (control constant for proportional control is fixed, for example)
P5
Instruct yarn treating apparatus shortly before target yarn length to change position (operating position of knotter, splicer, or the like, or position at which dyeing color is changed) and set-up yarn length become equivalent
P6

FIG. 6



: Normal control pattern
: Control pattern in the vicinity of course end and shortly before change position
+
Dead zone
Accumulated error
0
−
1
2
3
4
5
6
7
8
9
10
11
12
13
Needle number

F I G. 7



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EUROPEAN SEARCH REPORT

Application Number
EP 14 02 0020

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D04B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	27 May 2014	Wendl, Helen

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