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(71) Applicant: **Deimo S.p.A.**
25125 Villaggio Sereno (BS) (IT)

(72) Inventors:
- **Bellomi, Nicola**
  25125 Villaggio Sereno (BS) (IT)
- **Mattia, Mario**
  25125 Villaggio Sereno (BS) (IT)

(74) Representative: **Myon, Gérard Jean-Pierre et al**
Cabinet Lavoix Lyon
62, rue de Bonnel
69448 Lyon Cedex 03 (FR)

(54) Circular knitting machine

(57) Method for controlling the rotation of a lower cylinder (2) and a upper coaxial counter part (3) of a circular knitting machine, method comprising the steps of:
- driving with a first electric motor (M_1)the rotation of the lower cylinder (2),
- driving with a second electric motor (M_2) the rotation of the upper counterpart (3),
- detecting the angular position (φ_1) of the lower cylinder (3),
- detecting the angular position (φ_1) of the upper counter part,
- controlling electronically the rotation of the first (M_1) and second (M_2) motors by determining of a first set-point S_1 for the first motor and a second set-point S_2 for the second motor according to:
- the main set-point S provided by the knitting program,
- the difference between the detected position φ_1 of the lower cylinder and the detected position φ_2 of the upper counter part,
- and eventually the desired phase shift ξ between the lower cylinder and the upper counter part provided by the knitting program.

Knitting machine implementing such method.

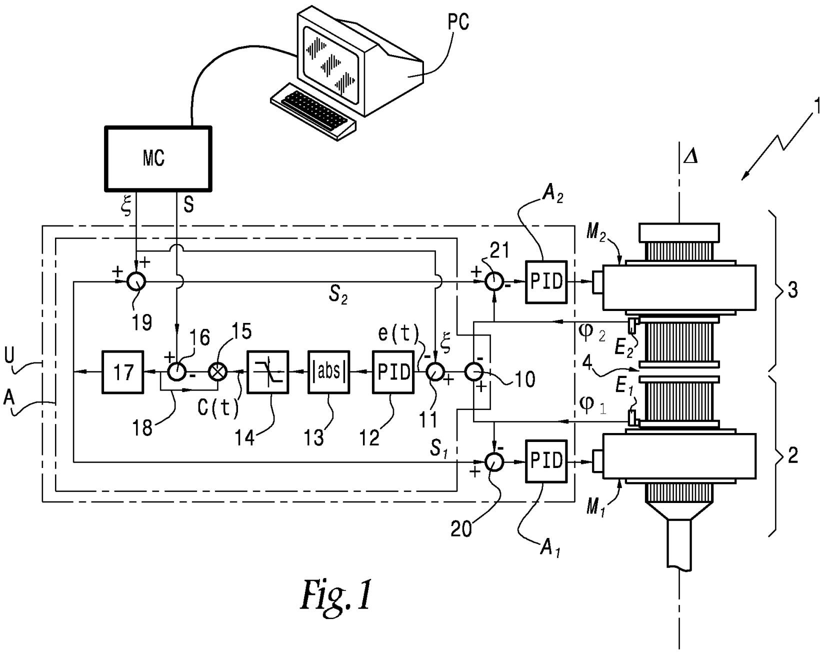

Fig.1

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Description

[0001] The present invention relates to circular knitting machines with either one or two cylinders. The invention relates more particularly to the control of the rotation of a cylinder and its counter part being another cylinder for a two-cylinder knitting machine or a dial plate for a single cylinder knitting machine.

[0002] Double cylinder knitting machines comprise generally two vertical coaxial cylinders facing head to head with a small space between them. Both cylinders have an equal number of grooves each adapted to hold a moving needle. Typically, each needle has stitches forming hooks at one of its ends. The two cylinders, respectively the lower and the upper one, rotate with their needle, holding grooves aligned. According to the required knitting pattern, some hooks are fed by a yarn finger near the rim of the cylinder, approximately at a middle of the space between them. From this middle point, the yarn can be taken by the hooks of the needle to form stitch. A needle taking in charge the yarn can be either in the groove of the upper cylinder or in the groove of the lower cylinder. It is also possible to modify the relative phase of the two cylinders in order to move, for example, the stitches diagonally in respect to the fabric or the knitted products so that the circular knitting machine is able to implement a range of knitting effects such as braid cable effect as it is possible on flat knitting machines.

[0003] It can be understood that the two cylinders must rotate while keeping their grooves aligned with a high degree of precision. The stitch being partly held by the needle of the upper cylinder and partly by needles of the lower cylinder and subject to be transferred from top to bottom or reversely according to the required knitting pattern, a loss of alignment will drain the stitches and even break the yarns and/or the needles hooks themselves. In the same manner, a loss of alignment or synchronism, while transferring a stitch from a cylinder to the other, could result in a needle break. Such breakage on a circular knitting machine is often of catastrophic consequences since the breakage propagates to many needles and mechanical parts requiring a servicing which can be quite costly and time consuming.

[0004] In order to prevent any risk of misalignment or loss of synchronism, on known double knitting machine the cylinders are driven by a unique electric motor associated with a mechanical transmission which is very expensive to manufacture and which introduces mechanical losses. Moreover, when there is a need to allow a desired phase shift between the needles cylinders, the mechanical transmission becomes even more complicated, expensive and difficult to handle and to service.

[0005] Single cylinder machines with dial plate generally comprise a bottom cylinder holding needles and a coaxial dial plate rotating above it and holding one hook for each needle. Upon activation the hook keeps the yarn caught by the needle or allows its release from the needle in order to generate effects like double welt socks. The synchronism of the cylinder and the dial plate is necessary when hooks cooperate with needles. The dial plate eventually supports cutting yarn device. The length of the cut yarn can be adjusted by varying the speed between the cylinder and the dial plate. The synchronism of the bottom cylinder and the dial plate in such single cylinder knitting machine is achieved by similar means as on double cylinder machines.

[0006] Therefore, there is a need for a new way to control the rotation of cylinders of knitting machines which should be less expensive than the known mechanical transmissions with the at least same reliability and more versatility.

[0007] In order to achieve this, the invention concerns a method for controlling the rotation of a lower cylinder and an upper coaxial counter part of a circular knitting machine, method comprising the steps of:

- driving with a first electric motor the rotation of the lower cylinder,
- driving with a second electric motor the rotation of the upper counter part,
- detecting the angular position of the lower cylinder,
- detecting the angular position of the upper counter part,
- controlling electronically the rotation of the first and second motors by determining of a first set-point S_1 for the first motor and a second set-point S_2 for the second motor according to:
  - the main set-point S provided by the knitting program,
  - the difference between the detected position φ_1 of the lower cylinder and the detected position φ_2 of the upper counter part,
  - and eventually the desired phase shift ξ between the lower cylinder and the upper counter part provided by the knitting program.

[0008] The implementation of two separate electric motors, one for the lower cylinder and the other for the upper counter part, allows a control of the rotation of these at a very low cost. Furthermore, the electronic control of the rotation of each motor allows achieving their synchronism without the need of any complicated and expensive gear transmission.

[0009] Furthermore, in case of failure of one of the motors or its associated encoder, the other one is safely driven to stop in full synchronism.

[0010] According to a possible implementation of the invention, the method further comprises the steps of:

- comparing the first set-point S_1 to the detected position φ_1 of the lower cylinder and providing the result of the comparison to a first controller dedicated to the first motor,
- comparing the second set-point S_2 eventually containing the desired phase shift ξ to the detected position φ_2 of the upper counter part and providing the result of the comparison to a second controller dedicated to the second motor.

[0011] According to an aspect of this way of implementing the invention, the dedicated first and second controllers are PID controllers.

[0012] According to another aspect of this way of implementing the invention, the determination of the first set-point S_1 and second set-point S_2 comprises the step of filtering with a PID filter the difference between the detected position φ_1 of the lower cylinder and the detected position φ_2 of the upper counter part and eventually the desired phase shift ξ between the lower cylinder and the upper counter part.

[0013] The invention concerns also a circular knitting machine comprising at least:

- a lower cylinder rotating around a vertical axis Δ,
- a first electric motor driving the lower cylinder,
- a first angular detector detecting an angular position φ_1 of the lower cylinder,
- an upper counter part coaxial with the lower cylinder and rotating around the vertical axis Δ,
- a second electric motor driving the upper counter part,
- a second angular detector detecting an angular position φ_2 of the upper counter part,
- a control unit connected to the first and second electric motor, to the first and second angular detectors, to a machine controller running a knitting program, and adapted to control the rotation of the cylinder and the upper counter part according to the method according to the invention.

[0014] According to an implementation of the invention, the control unit comprises:

- a first dedicated controller adapted to control the first motor,
- a second dedicated controller adapted to control the second motor,
- a main controller which is adapted to determine a first set-point S_1 and a second set-point S_2 from :
  - a main set-point S, and eventually a desired phase shift ξ provided by the machine controller,
  - the difference between the detected position φ_1 of the lower cylinder and the detected position φ_2 of the upper counter part,

  and which is adapted to provide the first set-point S_1 and second set-point S_2 to respectively the first and second controller.

[0015] According to an aspect of this implementation of the invention:

- the first dedicated controller is a PID controller adapted to control the first motor according to the difference between the first set-point S_1 and the first angular position φ_1,
- the second dedicated controller is a PID controller adapted to control the second motor according to the difference between the second set-point S_2 eventually containing the desired phase shift ξ and the second angular position φ_2.

[0016] According to another aspect of this implementation of the invention, the main controller comprises a PID filter adapted to filter the difference between the first angular position φ_1, the second angular position φ_2 and eventually the desired phase shift ξ.

[0017] According to the invention, the knitting machine may be a single cylinder machine, the upper counter part being a dial plate or sinker. The knitting machine may also be a double cylinder machine, the upper counter part being then a second cylinder.

[0018] The various above aspects, embodiments or objects of the invention may be combined in various ways with each others provided that the combined aspects, embodiments or objects are not incompatible or mutually exclusive.

[0019] Other aspects and advantages of the present invention will be apparent from the following detailed description made in conjunction with the accompanying drawing illustrating schematically a non-limitative embodiment of the invention corresponding to a two cylinder knitting machine.

[0020] A circular knitting machine according to the invention, as shown on figure 1 and designated as a whole by reference number 1, comprises a lower cylinder 2 rotating around a vertical axis Δ. Above the lower cylinder 2, the circular knitting machine 1 comprises an upper coaxial counter part 3 also rotating around the vertical axis Δ. As on the shown example, the circular knitting machine is a double cylinder knitting machine, the counter part 3 is also a cylinder with its needles, not shown, extending at its lower part, whereas the needles of the lower cylinder 2 extend at the upper part of this lower cylinder. The needles of both the lower 2 and upper 3 cylinders cooperate with each other in order to form stitches in a middle part 4 so as to knit for example hosiery or other articles. According to a well-known technology to the people skilled in the art, the needles are set in grooves of the upper and lower cylinders and are able to change position according to a knitting program. The other elements of the knitting machine such as the Jacquard actuators of the needle, cams, sinkers, the yarns fingers, etc... are also well-known by the people skilled in the art and therefore do not need further description.

[0021] According to the invention, the lower cylinder 2 is driven by a first electric motor M_1 dedicated only to the rotation of the lower cylinder 2. In a same manner the upper counter part 3 is driven by a second electric motor M_2 also dedicated only to the rotation of said upper counter part 3. On the shown example, electric motors M_1 and M_2 are hollow shaft multi-poles motors. In order to provide a sufficiently high angular precision, the motors will preferably have more than twelve poles and, for example, twenty-four poles. The motors M_1 and M_2 will also be sized in order to allow rotating speeds up to 1000 RPM, for example. Naturally, any other kind of electric motors may be implemented such as traditional brushless motors with belts.

[0022] As there is a need to know accurately the angular positions of the lower cylinder 2 and the upper counter part 3, they are each provided with respectively a first angular detector or encoder E_1 and a second angular detector or encoder E_2.

[0023] The control of the rotation and the synchronization of the lower cylinder 2 and the counter part 3 is done by a control unit U receiving instructions from a machine controller MC running a knitting program and controlling accordingly the other functions of the machine. The machine controller MC is also connected to a user interface programming unit PC. The Machine controller MC provides to the control unit U a set-point S and a desired phase shift ξ between the cylinders 2 and 3 according to the knitting program.

[0024] In order to achieve its controlling functions, the control unit U is connected to the motors M_1, M_2, the angular detectors E_1, E_2 as well to the machine controller MC. The control unit U implements various functions which may be set on a same board or on different boards. These functions may also be emulated by a same electronic device or by different electronic devices depending on the knitting machines design.

[0025] On the shown example, the control unit U comprises a main or master controller A providing instructions to a first dedicated controller A_1 controlling first electric motor M_1 and to a second dedicated controller A_2 controlling the second electric motor M_2.

[0026] The main controller A comprises a first comparator or summator 10 which makes the difference between the first angular position φ_1 of the lower cylinder 2 as provided by the first angular detector E_1 and the second angular position φ_2, as provided by the second angular detector E_2, of the upper counter part 3. The first comparator 10 is followed by a second comparator 11 which is provided with both the result of the comparison achieved by the first comparator 10 and the desired phase shift ξ. After the second comparator 11, the main controller A comprises a PID (Proportional, Integral and Derivative) filter or controller 12 which provides its output to an absolute function block 13. The function block 13 is followed by an upper and lower bounding function 14 limiting the upper and lower values provided by the absolute function block 13. The output of the upper and lower bounding function block 14 is then provided to a multiplicator 15. The output of the multiplicator 15 is then provided to a comparator or substractor 16 also fed with the set-point S from the machine controller MC. The main controller A comprises also a low pass filter 17 receiving the result of the treatment conducted by the comparator 16. The main controller A is also provided with a feed back loop 18 feeding the result of the output of the comparator 16 to the multiplicator 15.

[0027] The output of the low pass filter 17 corresponds to a first set-point S_1 which will be used for controlling the first electric motor M_1 whereas a second set-point S_2 used for controlling the second electric motor M_2 will correspond to the output of a summator 19 provided with the output of the low pass filter 17 and the desired phase shift ξ.

[0028] The first set-point S_1 provided by the main controller A is fed to a comparator 20 receiving also the first angular position φ_1. The output of the comparator or substractor 20 is then provided to the first dedicated controller A_1 being a PID controller driving the first electric motor M_1. In a same manner, the second set-point S_2 determined by the main controller A is provided to a comparator or substractor 21 with the second angular position φ_2. The output of the comparator 21 is then provided to the second dedicated controller A_2 being here also a PID controller controlling the second electric motor M_2.

[0029] It should be noted that since the variable S, S_1, S_2, φ_1, φ_2, ξ are time dependent, they can also be noted as S (t), $S_1(t)$, $S_2(t)$, $\varphi_1(t)$, $\varphi_2(t)$, $\xi(t)$.

[0030] The control unit as disclosed above implements the method for controlling the rotation of the lower cylinder 2 and the upper coaxial counter part 3 of the circular knitting machine 1 as it follows.

[0031] The angular positions of each cylinder $\varphi_1(t)$ and $\varphi_2(t)$ may be defined as the angle covered by a fixed point on the cylinder, for example, a specific groove #1, at time t in respect to a fixed position (zero-position).

[0032] If $\varphi_1(t)$ and $\varphi_2(t)$ are the angular positions of cylinders 2 and 3 then the following relationship must be respected in order to avoid any default or breakdown

$$\text{Eq. 1} \qquad e(t) = |\varphi 1(t) - \varphi 2(t)| < MaxErr$$

[0033] Where e(t) is the phase-shift error function between axes and the MaxErr value is the minimum value of the e (t) function that generates mechanical breakings when exceeded.

[0034] In some particular cases, it might be necessary to be able to change the synchronism between the both cylinders in order for example, to realise special knitting effect known as braid or cable effect. Therefore, it is needed to allow one cylinder to be rotated relatively to the other one of one groove angular division so that each bottom cylinder groove is in front of a different top cylinder groove than initially. Such phase shift adjustment may also be needed when the machine is powered up for the first time in order to re-synchronize the cylinders. In those cases, a time dependant desired phase-shift ξ(t) function will be applied to one of the cylinder control device. The condition to keep a satisfying control will then be:

$$\text{Eq. 2} \qquad |\varphi 1(t) - \varphi 2(t) - \xi(t)| = e(t) < MaxErr \qquad e(t) \geq 0$$

[0035] In this case, the phase-shift error e(t) incorporates the desired phase-shift ξ(t).

[0036] It should be noted that the synchronism between the both motors must also be kept in case of a power failure and when the machine is powered up again. Naturally, the cylinders can be resynchronized only if the needles are all devoid of stitches, and no needle is midway between them.

[0037] In order to achieve a good synchronism of the rotation of the lower cylinder and its upper counter part 3, the main unit generates the position set-point S_1 and S_2 according to:

- the position set-point S issued by the machine controller MC,
- the difference between the positions of φ_1 and φ_2,
- and eventually the desired phase shift ξ(t) issued by the machine controller MC.

[0038] The input of PID filter 12 is the phase shift error e(t) and the output of the upper and lower bounding block 14 is a function c(t) which is 0 if the phase-shift error e(t) is null and becomes big in case the phase-shift error e(t) increases.

[0039] Because of the multiplicator 15, comparator 16, low pass filter 17 and feed back loop 18, the transfer function giving the first set-point S_1 is:

$$\text{Eq. 3} \qquad S_1(t) = \frac{1}{1+c(t)} * e(t)$$

[0040] When c(t) is close to zero the Set-point S_1 and the Set-point S are nearly the same function. If the value of c (t) is so big to make 1 negligible the set-point S_1 tends to 0. Same behaviour is true for the second set-point S_2 except for the sum of the desired phase-shift ξ(t). At the equilibrium:

$$\text{Eq. 4} \qquad |(\text{set-point } S_1) - (\text{set-point } S_2)| = \xi(t)$$

[0041] Therefore, once the system is balanced, the set-point of each cylinder can be replaced by its angular position:

$$\text{Eq. 5} \qquad |\varphi_1(t) - \varphi_2(t)| = \xi(t)$$

[0042] The PID filter 12 reduces the e(t) value in order to achieve the condition of the relation Eq. 2.

[0043] During normal operation, both cylinders rotate synchronously and phase shift is within what is tolerated. If a default occurs, for example M_2 motor fails, the phase shift error e(t) increases and causes c(t) to increase. Since c(t) is subtracted to the Set-point S(t) coming from the machine controller MC, the value set-point S_1 is decreased in order to reduce the phase-shift error e(t). Since the M_2 power drive is out of order, the set-point S_2 or angular position $\varphi_2(t)$ will not be affected. Advantageously because of the design of the control unit according to the invention, it does not matter which axe fails. So if E_1 transducer fails, Set-point S_2 will be corrected in order to reduce the phase-shift error.

[0044] According to prior art, the control of the synchronism of the motion of two axes is usually achieved by considering one axis as master which receives the main set-point. The other one is considered as slave and receives the angular position of the master axis as set-point. In case of failure of the slave axis, the master axis is not driven consequently which is a major drawback of such prior art method of control.

[0045] By considering the difference between the angular positions of both axes to elaborate the set-point of each axis, according to the invention, each axis takes into account an eventual failure of the other. The implementation of a PID filter in the determination of the set-points of both axes provides a reliable and tunable way to perform a stable control.

[0046] Another advantageous effect of this kind of control is that it provides an adaptation to dynamics troubles. If the desired rotating speed becomes so high that one of the motors can not follow, the set-point S_1 and the set-point S_2 are corrected in order to respect MaxErr. It concretely leads to a reduction of the speed of the machine since the position of the bottom cylinder is usually used to synchronize all the machine functions.

[0047] In case both cylinders need to move one regarding to the other, a desired phase-shift function $\xi(t)$ is fed to the main controller A. This phase-shift is concretely added to set-point and to the phase shift error e(t) in such way that if S_2 makes no dynamics difficulty to respect MaxErr, the operation of the both cylinders is correct.

[0048] The desired phase-shift function $\xi(t)$ is eventually used in the determination of the set-point S_1 and the set-point S_2 in the meaning that it is not always required since the lower cylinder and the upper counterpart work mainly in full synchronism during knitting and that the desired phase-shift function $\xi(t)$ is only fully included to one of the set-point since its target is to change the relative angular positions.

[0049] Of course, desired phase-shift function $\xi(t)$ can be indifferently fully applied to one of the first set-points S_1 or S_2.

[0050] While the invention has been shown and described with reference to a certain embodiment thereof, it would be understood by those skilled in the art that changes in form and details may be made therein without departing from the spirit and scope of the invention as defined in the appended claims.

Claims

1. Method for controlling the rotation of a lower cylinder (2) and a upper coaxial counter part (3) of a circular knitting machine, method comprising the steps of:

   - driving with a first electric motor (M_1) the rotation of the lower cylinder (2),
   - driving with a second electric motor (M_2) the rotation of the upper counter-part (3),
   - detecting the angular position (φ_1) of the lower cylinder (3),
   - detecting the angular position (φ_1) of the upper counter part,
   - controlling electronically the rotation of the first (M_1) and second (M_2) motors by determining of a first set-point (S_1) for the first motor and a second set-point (S_2) for the second motor according to:
   - the main set-point (S) provided by the knitting program,
   - the difference between the detected position (φ_1) of the lower cylinder and the detected position (φ_2) of the upper counter part,
   - and eventually the desired phase shift (ξ) between the lower cylinder and the upper counter part provided by the knitting program.

2. Method according to claim 1, comprising the steps of:

   - comparing the first set-point (S_1) to the detected position (φ_1) of the lower cylinder and providing the result of the comparison to a first controller dedicated to the first motor (M_1),
   - comparing the second set-point S_2 eventually containing the desired phase shift (ξ) to the detected position (φ_2) of the upper counter part and providing the result of the comparison to a second controller dedicated to the second motor (M_2).

3. Method according to claim 2, **characterized in that** the dedicated first and second controllers are PID controllers.

4. Method according to any of claims 1 to 3, **characterized in that** the determination of the first set-point S_1 and

second set-point S_2 comprises the step of filtering with a PID filter the difference between the detected position (φ_1) of the lower cylinder (2), the detected position (φ_2) of the upper counter part (3) and eventually the desired phase shift (ξ) between the lower cylinder (2) and the upper counter part (3).

5. Method according to any of claims 1 to 4, **characterized in that** the knitting machine is a single cylinder machine and the upper counter part (3) is a dial plate.

6. Method according to any of claims 1 to 4, **characterized in that** the knitting machine is a double cylinder machine and the upper counter part (3) is a second cylinder.

7. Circular knitting machine comprising at least:

- a lower cylinder (2) rotating around a vertical axis Δ,
- a first electric motor (M_1) driving the lower cylinder (2),
- a first angular detector (E_1) detecting an angular position (φ_1) of the lower cylinder (3),
- an upper counter part (3) coaxial with the lower cylinder and rotating around the vertical axis Δ,
- a second electric motor (M_2) driving the upper counter part (3),
- a second angular detector (E_2) detecting an angular position (φ_2) of the upper counter-part (3),
- a control unit connected to the first (M_1) and second electric motor (M_2), to the first (E_1) and second (E_2) angular detectors, to a machine controller (MC) running a knitting program, and adapted to control the rotation of the lower cylinder (2) and the upper counter-part (3) according the method according to any of claims 1 to 6.

8. Circular knitting machine according to claim 7, **characterized in that** the control unit comprises:

- a first dedicated controller (A_1) adapted to control the first motor (M_1),
- a second dedicated controller (A_2) adapted to control the second motor (M_2),
- a main controller (A) which is adapted to determine a first set-point (S_1) and a second set-point (S_2) from :
- a main set-point (S), eventually a desired phase shift (ξ) provided by the machine controller (MC),
- the difference between the detected position (φ_1) of the lower cylinder and the detected position (φ_2) of the upper counter part,

and which is adapted to provide the first and second set-points (S_1-S_2) to respectively the first (A_1) and second (A_2) controllers.

9. Circular knitting machine according to claim 8, **characterized in that** :

- the first dedicated controller (A_1) is a PID controller adapted to control the first motor (M_1) according to the difference between the first set-point (S_1) and the first angular position (φ_1),
- the second dedicated controller (A_2) is a PID controller adapted to control the second motor (M_2) according to the difference between the second set-point (S_2) eventually containing the desired phase shift (ξ) and the second angular position (φ_2).

10. Circular knitting machine according to claim 8 or 9, **characterized in that** the main controller (A) comprises a PID filter (12) adapted to filter the difference between the first angular position (φ_1), the second angular position (φ_2) and eventually the desired phase shift (ξ).

11. Circular knitting machine according to any of claims 7 to 10, **characterized in that** the knitting machine is a single cylinder machine and the upper counter part (3) is a dial plate or sinker.

12. Circular Knitting machine according to any of claims 7 to 10, **characterized in that** the knitting machine is a double cylinder machine and the upper counter part (3) is a second cylinder.

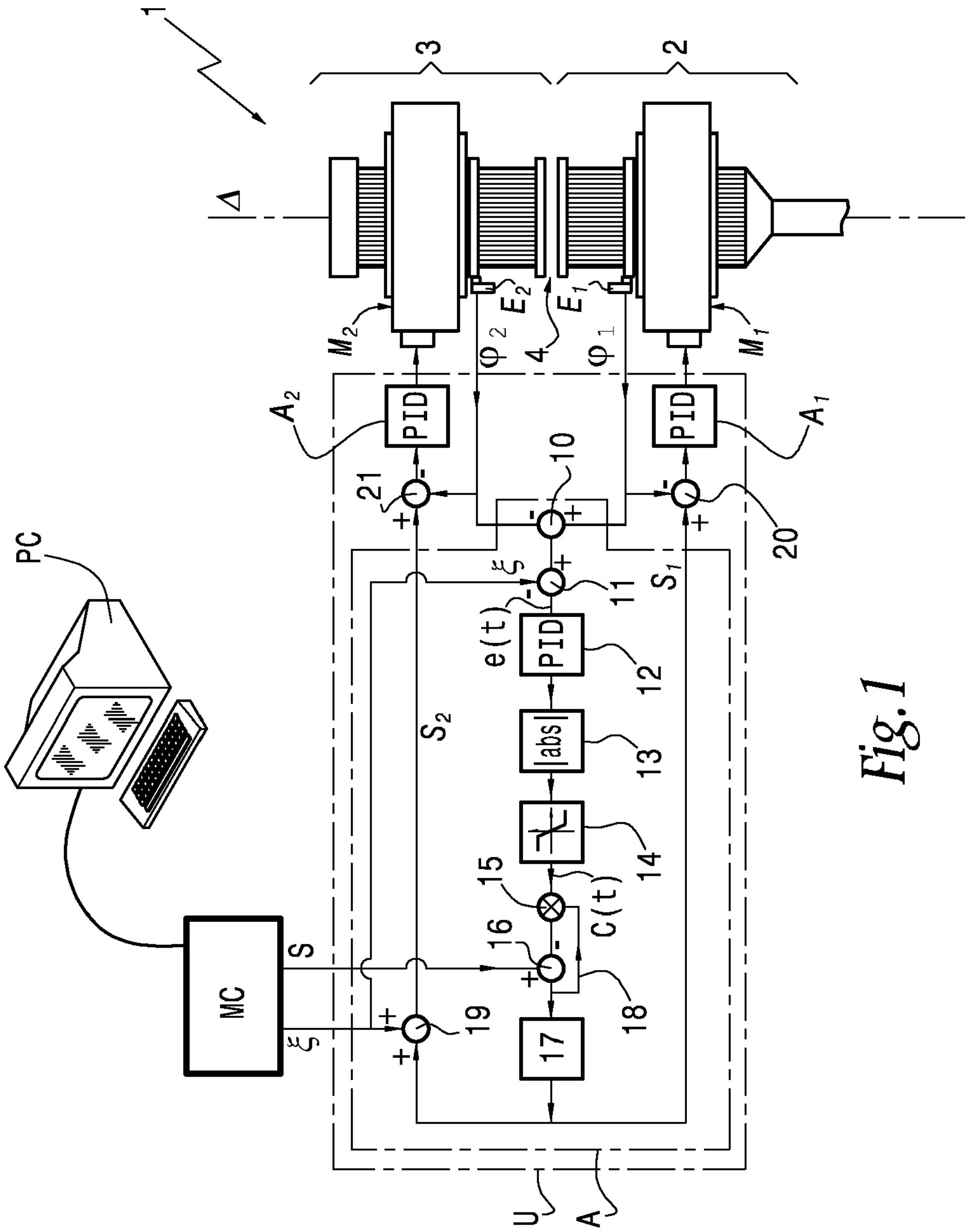
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Fig.1

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EUROPEAN SEARCH REPORT

Application Number
EP 08 16 1484

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

D04B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	15 January 2009	Pieracci, Andrea

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 08 16 1484

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