(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
9 April 2009 (09.04.2009)

PCT

(10) International Publication Number
WO 2009/043590 A2

(51) International Patent Classification:
B02C 4/06 (2006.01) *B02C 4/42* (2006.01)

(21) International Application Number:
PCT/EP2008/008396

(22) International Filing Date: 3 October 2008 (03.10.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
MI2007A 001920 5 October 2007 (05.10.2007) IT

(71) Applicant *(for all designated States except US)*: **BRATOS S.r.l.** [IT/IT]; Via Rovereto 19, I-15057 Tortona (Alessandria) (IT).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **BAIADA, Carlo** [IT/IT]; Via Ventimiglia, 121, I-41100 Modena (IT). **SAVINI, Mario** [IT/IT]; Via Verdi, 9, I-26041 Casalmaggiore (Cremona) (IT). **CAMATTI, Stefano** [IT/IT]; Via Puglie, 7, I-41056 Savignano Sul Panara, (Modena) (IT). **BRAMBATI, Alessandro** [IT/IT]; Via Cignoli, 63, I-27058 Voghera, (Pavia) (IT).

(74) Agent: **RAPISARDI, Mariacristina**; Ufficio Brevetti Rapisardi S.r.l., Via Serbelloni, 12, I-20122 Milano (DE).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI,

[Continued on next page]

(54) Title: ROLLER MILL AND PROCESS FOR GRINDING ALIMENTARY GRAINS

(57) Abstract: Roller mill for grinding alimentary grains has at least one pair of counter-rotating grinding rollers each controlled by an independent motor.

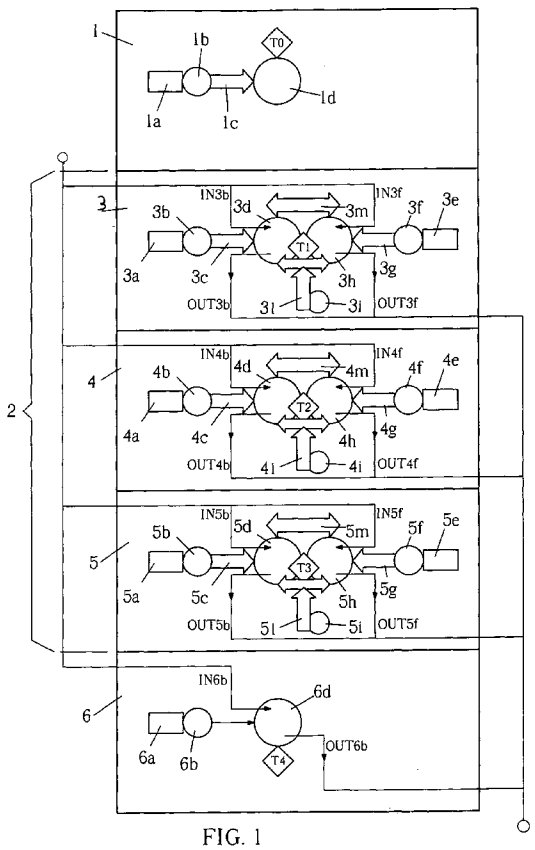

FIG. 1

WO 2009/043590 A2

FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *without international search report and to be republished upon receipt of that report*

ROLLER MILL AND PROCESS FOR GRINDING ALIMENTARY GRAINS

DESCRIPTION

The present invention refers to a roller mill and to a process for grinding alimentary grains in general, roasted or not roasted (coffee, barley, cocoa, peanuts, etc.).

It is known that in a roller mill for coffee the grinding of the bean is obtained by combined compression and cutting action on the bean itself.

Whereas the compression action is due to the combination of friction forces of the two counter-rotating rollers, the cutting action is due to the difference between the peripheral speeds of the two rollers: if the angular speed of the two rollers having equal diameters were the same, the cutting action would be zero.

A known mill is generally made up of a feeding section, a grinding section and a mixing section of the powders formed from the milling itself, the homogeneity of the distribution of the granulometry being extremely important for the quality of the milled product.

The grinding section is in turn generally made up of three sub-sections: breaking, finishing and super-finishing, the third sub-section of which is sometimes absent.

Each roller is equipped with more or less deep ribbing, studied so as to optimise the grinding effect for which that stage is intended, but one stage different to the other: each type of ribbing is optimised according to the task that the stage must perform (breaking, finishing or super-finishing)

CONFIRMATION COPY

and the type of coffee (Arabica, moka, etc.) that the mill has to grind.

As known, in each grinding sub-section the counter-rotating rollers are coupled with each other through a gearing that drives the motion from the drive roller to the driven roller. The drive roller is made to move by a transmission actuated by one or more motors. In the simplest architectures there is a single actuation motor for the entire grinding section, whereas there are architectures with a dedicated motor for each grinding sub-section.

In this configuration, when the mill is equipped with a motor for each grinding sub-section, it is possible to vary the speed of each drive roller from one sub-section with respect to the other, to optimise the grinding process.

When there is just one motor, the speed ratio between the various sub-sections is set by the parameters of the transmission itself.

In all cases, a different peripheral speed is obtained between the two rollers of the same sub-section acting upon the transmission ratio of the gear that drives the motion from the drive roller to the driven roller. This ratio is thus fixed, set by the construction of the mill itself: it is not possible to vary it apart from by physically intervening and proceeding to the dismounting of the gear wheels and their replacement.

It should be noted that the replacement of the rollers with others with ribbing more suitable for the new coffee being

ground or the replacement of the gears to vary the transmission ratio is an activity that requires many hours/workers with long idle times.

In the grinding process, it is of fundamental importance to be able to control both the size of the grain obtained downstream of each grinding stage and the temperature of the coffee, which must never exceed a very precise threshold otherwise the quality of the ground product obtained substantially degrades.

For this reason, the rollers are hollow and crossed on the inside by a current of cold water, just as the mixer of the mixing section is equipped with an outer lining defining a gap in which cooling water circulates.

The productivity of the mill (taken to be mass of coffee ground per unit time) is lower as the fineness of the ground grain increases, as the maximum temperature of the coffee has to be respected.

By fineness of the ground grain we mean the size of the coffee particle downstream of the grinding section.

The finer the grain, the greater the grinding work, the greater the energy transferred to the coffee and the greater the temperature increase if the time in which this grinding work is carried out is not increased, with a reduction in hourly productivity.

The flexibility of the mill, taken to be its ability to operate on different types of coffee (moka, Arabica, Napoli, etc.), is limited by the type of rollers installed: the mill

can operate just on coffee for which reason the ribbing of the mounted rollers have been optimised, all the whilst the ribbings are sufficiently deep, having not yet been reduced by wearing of the roller.

The adjustment of the mill, in the prior art, is limited to the adjustment of the distance between the two rollers by means of a micrometric mechanism, and to some adjustments of the speed when the motor or the motors are controlled by inverters.

Through the variation in distance, the compression force on the bean and, indirectly, the cutting force are acted upon, increasing the grinding effect as the distance between the rollers decreases, at the expense of an increased temperature of the ground product and a reduction in the lifetime of the rollers themselves.

N the case of a single motor for the entire grinding section, it will be possible to vary the speed of the entire section, leaving the ratios between the speeds of each pair of rollers and between the speeds of the sub-sections unchanged. These ratios are fixed by the mechanical parameters of the transmission.

In the case of a motor with an inverter for each sub-section, it will also be possible to vary the relative speed between one sub-section and the other, slowing down the sub-sections upstream if those downstream were unable to get through the ground product received.

It is important to observe that all of these adjustments are

made "by experience" through a trial-and-error system that generates a database available to the operator: in the prior art there are no detected parameters that can constitute a guide for the person operating and adjusting the mill.

The technical task proposed of the present invention is, therefore, to make a roller mill and a process for grinding alimentary grains that allow the aforementioned technical drawbacks of the prior art to be eliminated.

In this technical task, a purpose of the invention is to make a roller mill and a process for grinding alimentary grains that allow an improved joint performance both in terms of productivity and in terms of quality of the ground product.

Another purpose of the invention is to make a roller mill for grinding alimentary grains that has high flexibility to be used with different types of grains.

The last but not least purpose of the invention is to make a roller mill for grinding alimentary grains that can optimise grinding efficiency whilst respecting the process parameters to have better productivity combined with better quality of the ground product.

The technical task, as well as these and other purposes, according to the present invention, are accomplished by making a roller mill for grinding alimentary grains, having at least one pair of counter-rotating grinding rollers each controlled by an independent motor.

Preferably, each roller of each pair of counter-rotating grinding rollers of each grinding sub-section of the grinding

section has a respective independent motor controlled by a respective actuation, for example an inverter or an equivalent solution like a brushless motor or a vector-actuated AC motor, or with any controlled electric motor with an actuation.

The roller mill of the present invention can have an open-loop or preferably closed-loop adjustment system for controlling the rotation speed of each roller.

The closed-loop adjustment system can be of the type with or without speed sensors.

The roller mill of the present invention comprises means for detecting the temperature of the grains downstream of each grinding section or sub-section, and means for detecting the particle size of the grains downstream of each grinding section or sub-section for the adjustment of the process parameters.

The roller mill of the present invention advantageously foresees a process supervisor for the management of the production recipes.

The process for grinding alimentary grains with a roller mill of the present invention consists of varying the cutting effect on the grain by independently controlling the rotation speed of each roller of each pair of counter-rotating grinding rollers to vary the rotation speed ratio of each pair of counter-rotating rollers.

The cutting effect on the grain is varied to increase the grinding efficiency and/or to simulate different ribbings of

the rollers suitable for different types of grains, and/or to compensate for the variation in profile of the rollers due to wear that alters their ribbings.

Further characteristics and advantages of the invention shall become clearer from the description of a preferred but not exclusive embodiment of the roller mill and of the process for grinding alimentary grains according to the finding, illustrated for illustrating and not limiting purposes in the attached drawings, in which:

- figure 1 shows a functional bock diagram of the roller mill;
- figure 2 shows a functional diagram of the supervisor; and
- figure 3 shows a functional diagram of each grinding sub-section.

Hereafter, we shall refer specifically to the grinding of coffee powder even though the invention has a more general field of application for any alimentary grain.

The functional diagram of the section of the mill is illustrated in figure 1.

The mill comprises a feeding section 1, a grinding section 2 comprising, in sequence, a first breaking sub-section 3, a second finishing sub-section 4 and a third super finishing sub-section 5, and a mixing section 6.

The feeding section 1 comprises a group, formed from inverter 1a - motor 1b - reducer 1c, directly responsible for the rotation of the roller 1d.

The breaking sub-section 3 comprise a first group formed from

inverter 3a - motor 3b - reducer 3c, directly responsible for the rotation of the roller 3d, and a second group formed from inverter 3e - motor 3f - reducer 3g, directly responsible for the rotation of the roller 3h opposite the roller 3d.

The finishing sub-section 4 comprises a first group formed from inverter 4a - motor 4b - reducer 4c, directly responsible for the rotation of the roller 4d, and a second group formed from inverter 4e - motor 4f - reducer 4g, directly responsible for the rotation of the roller 4h opposite the roller 4d.

The super finishing sub-section 5 comprises a first group formed from inverter 5a - motor 5b - reducer 5c, directly responsible for the rotation of the roller 5d, and a second group formed from inverter 5e - motor 5f - reducer 5g, directly responsible for the rotation of the roller 5h opposite the roller 5d.

The mixing section 6 comprises a group formed from inverter 6a - motor 6b, directly responsible for the rotation of the roller 6d.

Upstream of the feeding section 1 there is a temperature sensor represented with a rhombus, just as downstream of each grinding sub-section and of the mixing section there is a temperature sensor represented with a rhombus. T0, T1, T2, T3 and T4, respectively are the temperatures detected by the sensors of the feeding section, of the first grinding sub-section, of the second grinding sub-section, of the third grinding sub-section and of the mixing section, respectively.

The temperature sensor can for example be a thermocouple or an optical pyrometer.

The logic unit of the adjustment system sends a set point value (indicated with IN3b for the motor 3b, IN3f for the motor 3f, IN4b for the motor 4b, IN4f for the motor 4f, IN5b for the motor 5b, IN5f for the motor 5f, IN6b for the motor 6b) to each motor at least of the grinding section 2 and in particular also of the motor of the mixing section 6.

The rotation speed of each roller is detected by means of a suitable sensor (not shown) and is adjusted in closed loop. The output signal (indicated with OUT3b for the motor 3b, OUT3f for the motor 3f, OUT4b for the motor 4b, OUT4f for the motor 4f, OUT5b for the motor 5b, OUT5f for the motor 5f, OUT6b for the motor 6b) is returned to the logic unit. The closing in feedback can also be obtained without a sensor but rather through vector control of the rotation that allows the value of the real speed to be obtained.

In figure 1 it is also possible to see the system for adjusting the distance between the rollers in the grinding section 2: the motor 3i - reducer 3l group adjusts the distance between centres of the (parallel) rollers 3d and 3h and the position sensor/transducer 3m measures the distance between their centres; the motor 4i - reducer 4l group adjusts the distance between centres of the (parallel) rollers 4d and 4h and the position sensor/transducer 4m measures the distance between their centres remotely; and the motor 5i - reducer 5l group adjusts the distance between

centres of the (parallel) rollers 5d and 5h and the position sensor/transducer 5m measures the distance between their centres.

The motor of each system for adjusting the distance between the rollers uses the corresponding position sensor/transducer that controls their position for position feedback.

Since it is possible to vary the relative speed between the rollers, it is possible to vary the cutting effect on the bean being ground making the mill much more flexible, allowing the particle size of the ground product to be optimized not only by varying the compression by intervening on the distance between the rollers, or by replacing the rollers themselves with others with different ribbing, but also by having a more or less pronounced effect of the cut. As the ratio between the peripheral speeds of the two rollers increases with respect to 1:1 there is an increasingly pronounced cutting effect, which allows the efficiency of grinding to be increased and allows different ribbings suitable for different types of grains to be simulated, advantageous for the flexibility of the mill.

The variation of the profile of the rollers due to the wear that alters the ribbings themselves can also be compensated.

Figures 2 and 3 show the outline diagram of the temperature control algorithm.

In the supervision stage the setpoints of the individual sub-sections of the grinding section 2 are determined (T1setp for

sub-section 3, T2setp for sub-section 4□ T3setp for sub-section 5) calculating them based upon a parameter (indicated with "E" in figure 2) that takes into account the exit temperature of the ground coffee (T4) and a maximum freely settable value (Tmax), and based upon a "vertical" temperature profile (T1prof, T2prof, T3prof) that will be followed by the coffee in passing from the first to the last grinding sub-section.

Having calculated the setpoints (T1setp, T2setp, T3setp), the control passes to the PID (proportional-integral-derivative) algorithms that control slip (difference in angular speed between the opposite rollers of the same diameter of each grinding sub-section) and squashing (distance between centres of the rollers of the same diameter of each grinding sub-section) with different weights (represented by the rhombus with the symbol %) that can be freely set by the user.

In figure 3, i indicates the grinding sub-section (i=3,4,5), Ti (as stated previously) indicates the real temperature detected downstream of the grinding sub-section, Ei indicates the shift between Tisetp and Ti, Si indicates the slip in the sub-section i, and Pi indicates the squashing in the sub-section i.

From the PID that controls slip it is preferable to have directly in output the speed value of the fast roller, the speed of the slow roller being fixed based upon the desired hourly production value. The desired speed value shall be

obtained by acting directly on the inverter that controls the motor that actuates the fast roller.

The PID that controls squashing, in output gives the value of the distance between centres of the rollers. This shall in turn be the setpoint of an ON/OFF algorithm that, by using a position transducer as position feedback of the motor of the mechanism for moving the rollers, controls their position.

Advantageously, through the supervisor schematized in figure 2 production recipes can be managed.

It should also be highlighted how by detecting the temperature downstream of each grinding sub-section it is possible to optimize the grinding effect, reducing the particle size in each sub-section to the minimum, with an advantage for productivity without risking a decrease in the quality of the powder, but rather being able to ensure the maximum adherence to the process parameters.

In other words, it is possible to push the reduction in particle size on the previous grinding sub-section to the maximum, increasing the cutting effect on the rollers of the grinding sub-section upstream and decreasing the distance between the rollers, making the work of the subsequent sub-section easier, without ever overheating the ground product, because its temperature is known.

By taking a small amount of powder with a suitable duct downstream of each sub-section it is also possible to perform direct particle size detections, optimizing the work recipes

experimentally, based upon the particle size spectrum detected by the particle size analyzer. The particle sizes downstream of each grinding sub-section can be detected by means of a particle size analyzer (three particle size analyzers, one for each grinding sub-section, or a single particle size analyzer that reads the three values in sequence.

Finally, it is advantageously possible to achieve a substantial energy saving in the management of the mill through a control system by which in the individual grinding sub-section the slower motor recovers the energy generated by the axis of the motor of the fast roller using a power bus (for example a DC bus) and returning it to the network.

The mill thus conceived can undergo numerous modifications and variants, all of which are covered by the inventive concept; moreover, all of the details can be replaced by technically equivalent elements.

In practice, the materials used, as well as the sizes, can be whatever according to requirements and the state of the art.

CLAIMS

1. Roller mill for grinding alimentary grains, characterised in that it has at least one pair of counter-rotating grinding rollers each controlled by an independent motor.

2. Roller mill for grinding alimentary grains according to claim 1, characterised in that it has a grinding section consisting of a plurality of grinding sub-sections in each of which there is a pair of counter-rotating grinding rollers each controlled by an independent motor.

3. Roller mill for grinding alimentary grains according to one or more of the previous claims, characterised in that each roller has a respective independent motor controlled by a respective actuation.

4. Roller mill for grinding alimentary grains according to one or more of the previous claims, characterised in that each roller has a system for adjusting its rotation speed.

5. Roller mill for grinding alimentary grains according to one or more of the previous claims, characterised in that said adjustment system is in a closed loop and comprises a sensor for detecting the real rotation speed of said roller.

6. Roller mill for grinding alimentary grains according to one or more of the previous claims, characterised in that said adjustment system is in a closed loop and comprises a vector controller from which the real rotation speed of said roller is obtained.

7. Roller mill for grinding alimentary grains according to one or more of the previous claims, characterised in that it comprises, downstream of each grinding sub-section, means for detecting the temperature of said grains.

8. Roller mill for grinding alimentary grains according to one or more of the previous claims, characterised in that it comprises, downstream of each grinding sub-section, means for detecting the particle size of said grains.

9. Roller mill for grinding alimentary grains according to one or more of the previous claims, characterised in that each pair of rollers has an associated energy recoverer that transfers energy from the axis of the motor of the fast roller to the axis of the motor of the slow roller returning I to the network using a power bus.

10. Roller mill for grinding alimentary grains according to one or more of the previous claims, characterised in that it comprises a process supervisor for managing the production recipes.

11. Process for grinding alimentary grains with a roller mill, characterised in that it consists of varying the cutting effect on said grains by independently controlling the rotation speed of each roller of each pair of counter-rotating grinding rollers to vary the rotation speed ratio of each pair of counter-rotating rollers.

12. Process for grinding alimentary grains with a roller mill according to the previous claim, characterised in that the

cutting effect on said grains is varied to increase the grinding efficiency.

13. Process for grinding alimentary grains with a roller mill according to one or more of the previous claims, characterised in that the cutting effect on said grains is varied to simulate different ribbings of the rollers suitable for different types of said grains.

14. Process for grinding alimentary grains with a roller mill according to one or more of the previous claims, characterised in that the cutting effect on said grains is varied to compensate for the variation in profile of the rollers due to wear that alters their ribbings.

15. Process for grinding alimentary grains with a roller mill, characterised in that the process parameters are adjusted by detecting the temperature of said grains and/or their particle size downstream of each grinding sub-section.

16. Process for grinding alimentary grains with a roller mill according to one or more of the previous claims, characterised in that the indication of the temperature detected downstream of the grinding sub-sections is used to control the slip and the distance between centres of the counter-rotating rollers of each grinding sub-section so as to maximise the reduction in particle size in each grinding sub-section.

17. Roller mill and process for grinding alimentary grains as described and claimed.

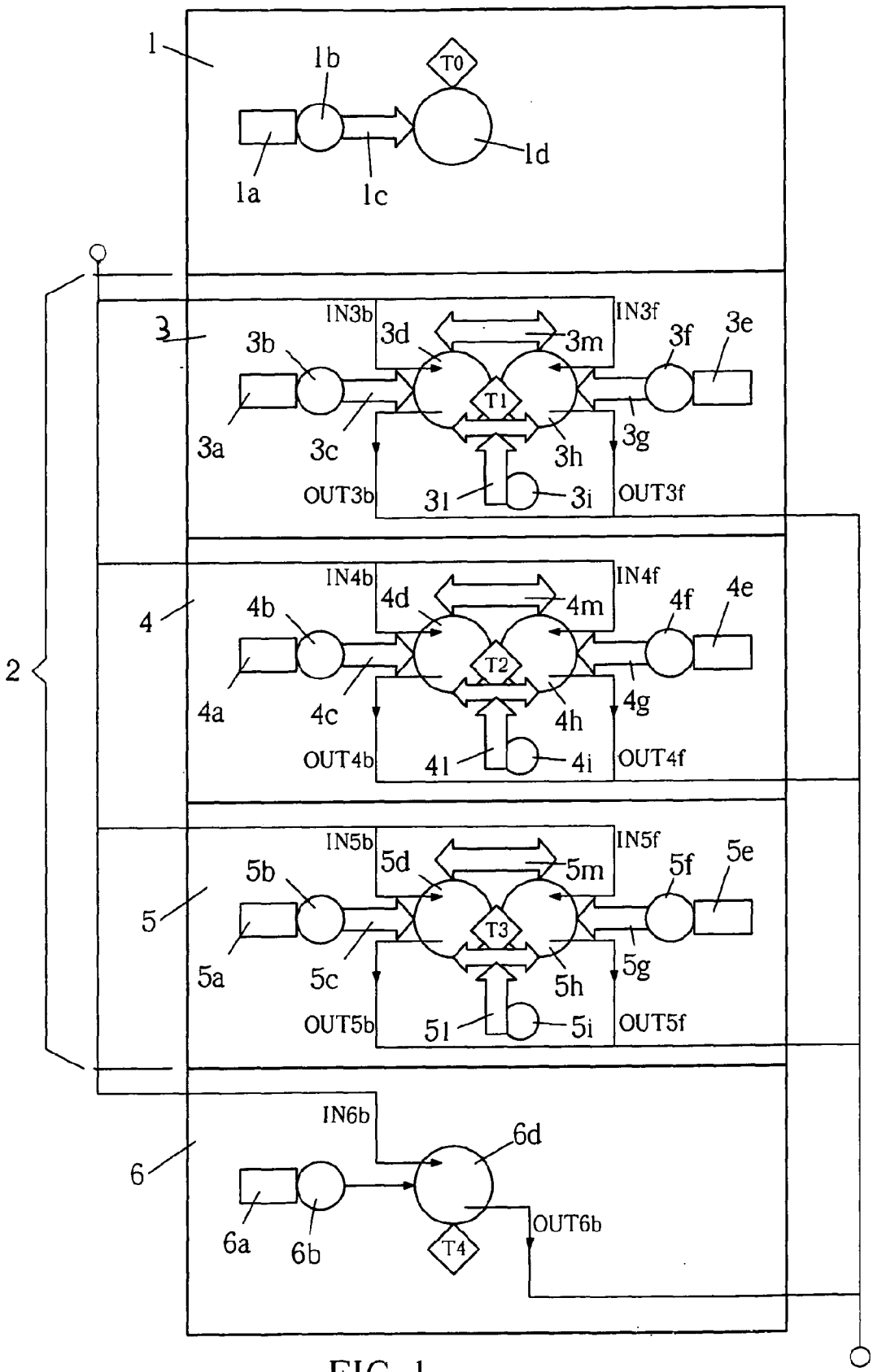
1
1b
T0
1d
1a
1c
2
3
IN3b
3d
IN3f
3m
3b
3f
3e
T1
3a
3c
3h
3g
OUT3b
3l
3i
OUT3f
4
IN4b
4d
IN4f
4m
4b
4f
4e
T2
4a
4c
4h
4g
OUT4b
4l
4i
OUT4f
5
IN5b
5d
IN5f
5m
5b
5f
5e
T3
5a
5c
5h
5g
OUT5b
5l
5i
OUT5f
6
IN6b
6d
6a
6b
T4
OUT6b

FIG. 1

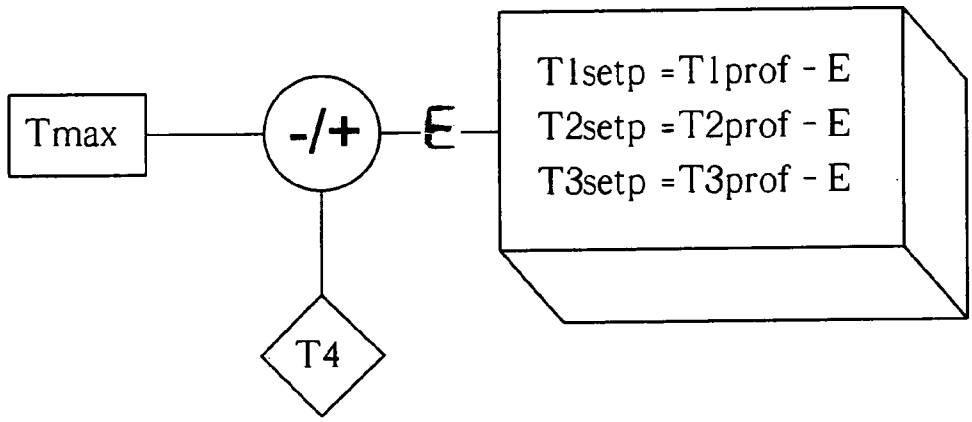
Tmax
-/+
E
T1setp =T1prof - E
T2setp =T2prof - E
T3setp =T3prof - E
T4

FIG. 2

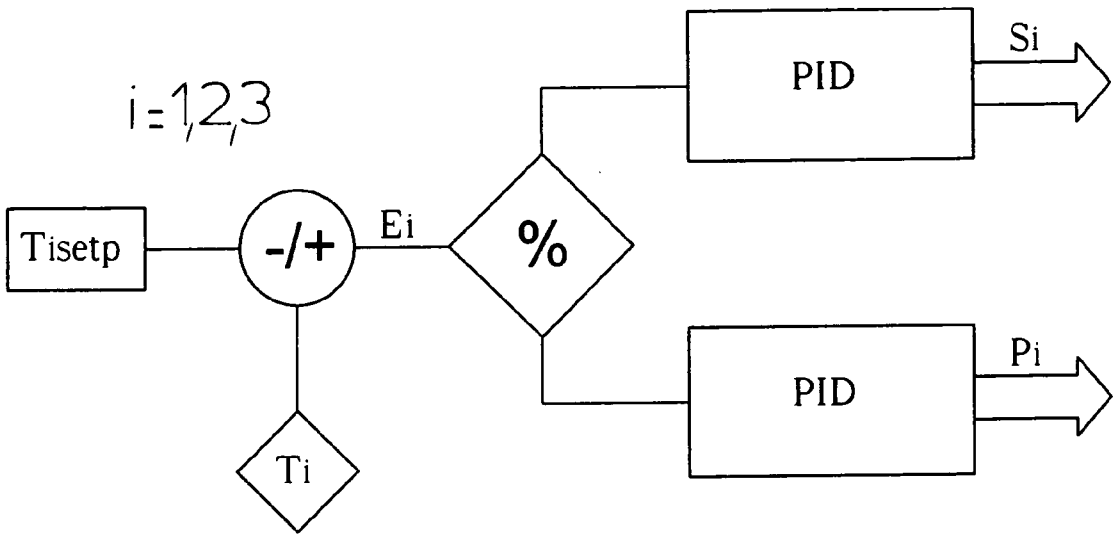
i=1,2,3
Tisetp
-/+
Ei
%
PID
Si
PID
Pi
Ti

FIG. 3