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The present invention relates to a method of operating a pivot drive, in particular a rotary indexing table, having a turntable which can be driven by a motor to make a rotational
5 movement about an axis of rotation.

Rotary indexing tables are in widespread use, for example, in assembly and automation technology. Workpieces are arranged on the turntable and are set into continuous or clocked rotational movements for their machining and/or assembly. In this respect, the
10 precision of the rotational movement is of special significance so that the workpiece always has well-defined positions/orientations relative to the respective assembly tools or processing tools.

It is understood that the operational behavior of a pivot drive or of a rotary indexing table
15 depends on the external strains. In other words, the behavior of a pivot drive changes when the strains acting on it are changed. In addition, wear phenomena at components of the pivot drive or a replacement of components can have the result that the behavior of the pivot drive is changed. The named causes can go so far that the required movement profile of the turntable can no longer be produced in the required precision by the pivot drive.

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EP 2 093 642 A1 discloses a turntable having a table plate, wherein an inductive ring sensor delivers angular data for monitoring the rotary movement of a drive roller, wherein the actual zero position delivered by the sensor is compared with an ideal zero position. In the case of a deviation of the actual zero position from the ideal zero position of more than
25 five degrees, the switch-off point is automatically corrected to minimize the determined deviation.

It is therefore the object of the present invention to provide a method for an operation of a pivot drive which is as reliable and as precise as possible and by which in particular

different operating states can be taken into account. The method should moreover be as simple as possible to implement.

This object is satisfied by a method having the features of claim 1.

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The method in accordance with the invention is used in a pivot drive having a turntable which can be driven by a motor to make a rotational movement about an axis of rotation. At least one sensor, which delivers angular data and which is connected to a control device, is provided for monitoring a rotational movement of the motor, of the turntable
10 and/or of a rotating component of a drive train arranged between the motor and the turntable. In accordance with the invention, the sensor data are compared with predefined DESIRED data stored in the control device to adapt at least one parameter characterizing or influencing the rotational movement on a deviation of the sensor data from the DESIRED data to minimize the determined deviation.

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In other words, the operation of the pivot drive is monitored by a sensor, with the monitoring not necessarily having to take place directly at the turntable or at the motor. The sensor can also, for example, be arranged so that it monitors the rotational movement of one or more components of a transmission disposed between the motor and the
20 turntable. It is also possible to provide a plurality of sensors whose data are compared with one another to be able to initiate corresponding countermeasures in the case of deviations which indicate a malfunction.

In this respect, the monitoring serves the purpose of identifying a contour error which
25 indicates the deviation between an ACTUAL position of the component monitored by the sensor and a DESIRED position thereof. If the turntable is, for example, at a specific time located in a rotational/angular position (ACTUAL value) which does not correspond to a predefined rotational/angular position (DESIRED value), it is recognized that a contour error is present. To reduce this, at least one parameter is varied which characterizes the
30 rotational movement or influences it.

The parameter characterizing the rotational movement is, for example, a speed, an acceleration of the turntable or a drive parameter which reflects the state of the drive of the pivot drive such as a power consumption or other operating parameters of a drive motor.

5 However, not only a fixed value which characterizes the rotational movement at a specific time or in a specific rotational position is to be understood as a parameter. It can also be understood as a function. That is, a determined contour error can, for example, be utilized to adapt a speed profile or an acceleration profile of the turntable movement to minimize the contour error.

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In order not to generate any overregulation of the turntable movement, provision can be made that the sensor data are determined during a measuring cycle which comprises a predetermined time period or a predetermined amount of the rotational movement. The determined sensor data (ACTUAL values), which are, for example, present in the form of a
15 predetermined number of discrete individual data, with the predetermined number depending, for example, on the resolution behavior of the sensor, are compared with the corresponding DESIRED values to determine an ACTUAL/DESIRED error which is specific to a measuring cycle and which is used as a basis for the adaptation of at least one parameter. Such a measuring cycle can, for example, comprise one or more movement
20 cycles of the turntable.

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After one movement cycle, a cumulative contour error is calculated which is determined from the individual comparisons of the ACTUAL values with the DESIRED values and which forms the basis for the adaptation of one or more parameters of the rotational
25 movement for the next cycle.

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The measuring cycle can comprise at least two measuring intervals for which a respective ACTUAL/DESIRED error is determined which is specific to the measuring interval, with the ACTUAL/DESIRED error specific to the measuring cycle being determined by an
30 averaging of the ACTUAL/DESIRED error specific to the measuring interval. A

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measuring cycle comprises 5 movement cycles of a rotary indexing table, for example. A contour error is determined for each cycle. An averaged contour error is in turn calculated from the obtained 5 contour errors and is used for adapting the parameter.

- 5 Provision can be made that individual values of the sensor data are compared with corresponding individual values of the DESIRED data during the measuring cycle to continuously update an ACTUAL/DESIRED error and to compare it with a threshold value. On an exceeding of the threshold value, an error message can be output. This measure makes it possible to abort the measuring cycle when contour errors occur which
- 10 are too large. This is the case, for example, when a serious disturbance is present (e.g. blockage of the turntable) which could possibly result in serious damage on a further operation of the pivot drive.

The turntable is preferably driven to make a clocked rotational movement, with the

15 turntable in particular being in a position of rest between two cycles. As already mentioned, the above-named measuring cycle can comprise one or more cycles of the movement of the turntable.

In accordance with an advantageous embodiment, a teaching cycle comprising a

20 predetermined number of measuring cycles is completed for a teaching process for determining a value of the at least one parameter suitable for a standard operation of the pivot drive or a function of the at least one parameter suitable for a standard operation. The at least one parameter or its function is adapted iteratively in the course of the teaching cycle to minimize the deviation. At least two parameters or their functions are in particular

25 adapted in the course of the teaching cycle, with preferably only one parameter or its function being changed per measuring cycle.

The teaching process can comprise a predetermined number of teaching cycles to obtain a parameter value set or a set of functions of the parameter, with the parameter set or the

function set being averaged to determine an averaged parameter value suitable for a standard operation or a suitable averaged function of the parameter.

Provision can be made to carry out the teaching process in a non-loaded state of the pivot
5 drive and/or in a loaded state of the pivot drive. Different load states are preferably taught to be able to make use of previously taught values on changes of load without a repeat teaching process having to be carried out. It is understood that the teaching process can already take place ex works or at the deployment site of the pivot drive.

10 At least one threshold value can be determined on the basis of the value of the parameter suitable for a standard operation or of the function of the parameter suitable for a standard operation, with an exceeding and/or falling below of said threshold value triggering an error message or a monitoring message in a standard operation of the pivot drive. In other words, the parameter value or its function is itself used to determine a tolerance range. As
15 long as the contour error does not move out of the tolerance range, it is assumed that the pivot drive is working properly. Only deviations which move out of the tolerance range result in error messages or a monitoring message. Such messages can be of an acoustic and/or optical type. Messages can also be output which result in an operating stop. The message can be used to indicate to a user that a new teaching process is required. Such a
20 process can also be initiated automatically.

The invention further relates to a pivot drive, in particular to a rotary indexing table, having a turntable which can be driven by a motor to make a rotational movement about an axis of rotation, wherein at least sensor, which delivers angular data and which is
25 connected to a control device, is provided for monitoring a rotational movement of the motor, of the turntable and/or of a rotating component of a drive train arranged between the motor and the turntable. The control device is configured to carry out the method in accordance with at least one of the above-described embodiments.

The turntable of the pivot drive can have drivers engaging into a drive groove of a barrel cam, with the turntable being able to be driven via the barrel cam to make the rotational movement about the axis of rotation, which barrel cam can in turn be driven by a motor to make a rotational movement about its longitudinal axis.

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Further embodiments of the invention are set forth in the description, in the drawings and in the dependent claims.

The invention will be described in the following purely by way of example with reference
10 to advantageous embodiments and to the enclosed drawing.

The only Figure schematically shows a rotary indexing table 10 which has a turntable 12 on which workpieces can be clamped for machining and/or assembly. The turntable 12 is driven by a barrel cam 14 to make a rotational movement about an axis of rotation R which
15 extends perpendicular to the plane of the Figure. To transmit a drive movement of the barrel cam 14 in the form of a rotation thereof about an axis of rotation R' perpendicular to the axis of rotation R of the turntable 12 to the turntable 12, the latter has drivers (not shown) which engage with a constant or varying pitch in a manner known per se into a drive groove (not shown) running around the barrel cam 14 spirally.

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The barrel cam 14 is rotationally fixedly connected to a drive shaft 16. The drive shaft 16 is in turn connected to an output of a transmission 18. Its input is connected to a motor shaft 20. The motor shaft 20 is driven by a motor 20 to make a rotational movement.

25 A rotary sensor 24 is arranged at the motor shaft 20, detects the rotational movement of the motor shaft 20 and transfers corresponding measured sensor values S to a control unit 26. The control unit 26 processes the measured sensor values S and evaluates them. The control unit 26 determines by a comparison of the measured sensor values S with reference values (ACTUAL/DESIRED comparison) whether the detected rotational movement
30 corresponds to the presets and, if necessary, adapts a parameter or a function of the

parameter which characterizes the rotational movement. For example, an acceleration profile is adapted which is required for generating the desired movement profile of the turntable 12. The acceleration profile ultimately in turn serves for controlling the drive power output by the motor 22. To realize this control, the control unit 26 communicates
5 control instructions A to the motor 22.

In other words, a closed loop is present which directly monitors the rotational movement of the motor shaft 20 of the motor 22 and ultimately exerts an effect on the rotational movement of the turntable 12 on the basis of the data determined in so doing in that the
10 control of the motor 22 is adapted.

Alternatively or additionally, a rotary sensor 24' (shown in dashed lines) can be provided which detects the rotational movement of the drive shaft 16 or its respective angular position and transmits corresponding measured sensor values S' to the control unit 26. If
15 only the sensor 24' is present, the drive power produced by the motor 22 is detected indirectly, whereas the rotational movement of the barrel cam 14 or its respective angular position is monitored directly. The monitoring thus takes place "closer" to the turntable 12, whereby effects which are difficult to quantify of the transmission 18, which cannot be produced completely free of play in practice, enter into the measured sensor values S'. In
20 other words, the measured sensor values S' as a rule represent the position of the turntable 12 better than the measured sensor values S since there only angular errors enter in connection with the driver-drive groove coupling, but not angular errors in connection with the transmission 18.

25 The control of the position of the turntable 12 also takes place via control instructions A to the motor 22 in this variant. The control instructions A are then determined in dependence on the measured sensor values S'.

In embodiments which have both sensors 24, 24', the measured sensor values S, S' can be
30 taken into account together, for example for diagnosing the state of the drive train of the

rotary indexing table 10 or of its components (e.g. transmission 18) or within the framework of a fine tuning of the operating parameters for its control.

It is understood that additionally or alternatively sensors can be provided at the turntable
5 12 and/or at rotating components of the transmission 18 to monitor the operation of the rotary indexing table 10.

To prepare the rotary indexing table 10 for a standard operation, it is tested under different conditions. A DESIRED data set is first stored in the control unit 26 and indicates which
10 angular position the monitored component should have at any given time. On a subsequent test run, it is determined whether the actual rotational movement which is determined by the sensor 24, 24' corresponds to the stored DESIRED values. This means that at specific times the angular position of the monitored, rotatably supported component is determined (ACTUAL value) and is compared with a corresponding DESIRED value. A deviation of
15 the ACTUAL value from the corresponding DESIRED value is called a contour error.

If an instantaneous ACTUAL/DESIRED deviation is present which exceeds a certain threshold value, the test run is interrupted or aborted since it can be assumed that a serious functional disturbance is present. Otherwise, the individual results of the discrete
20 ACTUAL/DESIRED comparisons are stored and are converted into a cumulative contour error at the end of a first measuring cycle. The measuring cycle can, for example, be defined by a certain time period or by a certain angle of rotation of the turntable. With a rotary indexing table for the clocked movement of a workpiece, it is obvious to use one or more movement cycles as a measuring cycle.

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The cumulative contour error of a measuring cycle allows statements on how large the deviation of the actual movement from the desired movement profile is. To minimize the cumulative contour error, at least one predefined parameter is changed which characterizes the movement profile of the turntable. This can, for example, be a speed or an acceleration.

30 It is also possible to adapt a speed profile or an acceleration profile to achieve a

minimization of the cumulative contour error. An acceleration ramp/acceleration function can, for example, be varied to accelerate the turntable from a position of rest more slowly or faster.

- 5 In the next measuring cycle, a cumulative contour error is again determined and compared with the preceding one. A decision is now taken on the basis of this comparison whether an increase or a decrease in the contour error has occurred. The previously changed parameter (or its function) is again changed in dependence on this. Alternatively, a different parameter can also be changed to achieve a better adaptation of the ACTUAL operation to
10 the predefined DESIRED conditions.

The above-described procedure is carried out for so long until an acceptable contour error is achieved. To design the process as more robust, provision can be made that a measuring cycle is divided into a plurality of measuring intervals. The contour errors determined in
15 the individual intervals are averaged to determine an averaged cumulative contour error which serves as the basis for an adaptation of at least one of the parameters. The teaching process admittedly thereby becomes somewhat more complex, but random "overshoots" or measuring errors thus have less weight.

- 20 It is understood that, alternatively or additionally, a plurality of teaching cycles can be carried out with a predetermined number of measuring cycles to obtain a plurality of parameter sets or function sets of the parameters which are in turn averaged.

At the end of the process there is an iteratively changed characteristic parameter which
25 generates a movement profile for the non-loaded state which comes closest to the wanted DESIRED profile. An optimized acceleration profile of the turntable is obtained, for example. It is understood that in many cases not only one parameter or its function is subjected to an optimization. With a little more effort, two or more parameters can also be optimized to adapt the movement profile of the turntable to the expectations.

The above-described method can be repeated for different load states in order thus to obtain different parameter sets or parameter function sets which can then be selected in standard operation in accordance with the respectively present demand profile. This does not preclude that the respective present load situation at the site of deployment is subjected
5 to a separate teaching process to obtain results which are as good as possible.

The method can be used in a plurality of different pivot drives and in particular in rotary indexing tables. In rotary indexing tables having a turntable which has drivers engaging into a drive groove of a barrel cam provided with at least one latching path and which is
10 therefore driven by a rotation of the barrel cam to make a clocked rotational movement, the method can in particular also advantageously be used to optimize a positioning of the drivers with respect to the latching path. It is the aim in this respect, for example, to bring a driver located in the latching path into an ideal starting position by a precise barrel cam movement (e.g. trailing) so that a subsequent acceleration phase can be exactly initiated.
15 The precision of the operation of the rotary indexing table required for this purpose can be ensured by the above-described method and its individual embodiments.

Reference numeral list

	10	rotary indexing table
5	12	turntable
	14	barrel cam
	16	drive shaft
	18	transmission
	20	motor shaft
10	22	motor
	24, 24'	rotary sensor
	26	control unit
	R, R'	axis of rotation
	S, S'	measured sensor values
15	A	control instruction

Patentkrav

1. Fremgangsmåde til drift af et svingdrev, særligt et roterende indeksbord, med en drejeplade (12), som af en motor (22) kan drives til en drejebevægelse om en drejeakse (R), hvor der er tilvejebragt mindst en sensor (24, 24'), som leverer sensordata og er forbundet med en styreanordning til
- 5 overvågning af en drejebevægelse af motoren (22), af drejepladen og/eller en roterende komponent af en drivlinje anbragt mellem motoren (22) og drejepladen (12), hvor sensordataene er vinkeldata, hvor sensordataene sammenlignes med forhåndsbestemte INDSTILLINGSVÆRDI-data lagret i styreanordningen for ved en afvigelse af sensordataene fra INDSTILLINGSVÆRDI-dataene at tilpasse mindst en parameter, som karakteriserer eller påvirker drejebevægelsen, med henblik på at
- 10 minimere den beregnede afvigelse,
- kendetegnet ved, at**
- sensordataene beregnes under en målecyklus, som omfatter et forhåndsbestemt tidsrum eller en forhåndsbestemt værdi af drejebevægelsen, og de beregnede sensordata sammenlignes med de tilsvarende INDSTILLINGSVÆRDI-data for at bestemme en målecyklusspecifik FAKTISK
- 15 VÆRDI/INDSTILLINGSVÆRDI-fejl, som benyttes som basis for tilpasningen af den mindst ene parameter, og at
- enkeltværdier af sensordataene under målecyklussen sammenlignes med tilsvarende enkeltværdier af INDSTILLINGSVÆRDI-dataene for kontinuerligt at opdatere en FAKTISK
- VÆRDI/INDSTILLINGSVÆRDI-fejl og sammenligne denne med en tærskelværdi, hvor der
- 20 særligt ved overskridelse af tærskelværdien afgives en fejlmelding.
2. Fremgangsmåde ifølge krav 1,
- kendetegnet ved, at**
- drejepladen (12) drives til en trinvis drejebevægelse, hvor drejepladen (12) befinder sig i en
- 25 hvileposition særligt mellem to trin.
3. Fremgangsmåde ifølge krav 1 eller 2,
- kendetegnet ved, at**
- den mindst ene parameter er en hastighed, en acceleration, en hastighedsfunktion, en
- 30 accelerationsfunktion eller en drivparameter.

4. Fremgangsmåde ifølge krav 1,

kendetegnet ved, at

målecyklussen omfatter mindst to måleintervaller, for hver af hvilke der bestemmes en

måleintervalspecifik FAKTISK VÆRDI/INDSTILLINGSVÆRDI-fejl, hvor den

5 målecyklusspecifikke FAKTISK VÆRDI/INDSTILLINGSVÆRDI-fejl bestemmes via en melding

om den måleintervalspecifikke FAKTISK VÆRDI/INDSTILLINGSVÆRDI-fejl.

5. Fremgangsmåde ifølge krav 1 eller 4,

kendetegnet ved, at

10 målecyklussen omfatter et eller flere trin af drejepladens (12) bevægelse.

6. Fremgangsmåde ifølge et af kravene 1, 4 eller 5,

kendetegnet ved, at

der til en læreproces til bestemmelse af en værdi eller en funktion af den mindst ene parameter, som

15 egner sig til standarddrift, gennemføres en lærecyklus omfattende et forhåndsbestemt antal

målecyklusser, hvor den mindst ene parameter eller dennes funktion tilpasses iterativt i løbet af

lærecyklussen for at minimere afvigelsen.

7. Fremgangsmåde ifølge krav 6,

20 **kendetegnet ved, at**

der i løbet af lærecyklussen tilpasses mindst to parametre eller disses funktioner, hvor der særligt

kun ændres en parameter eller dennes funktion pr. målecyklus.

8. Fremgangsmåde ifølge krav 6 eller 7,

25 **kendetegnet ved, at**

læreprocessen omfatter et forhåndsbestemt antal lærecyklusser for at opnå et parameterværdisæt

eller et sæt af tidsmæssige funktioner af parameteren, hvor der beregnes et gennemsnit af

parametersættet eller funktionssættet for at bestemme en gennemsnitlig parameterværdi eller en

gennemsnitlig funktion af parameteren, som egner sig til standarddrift.

30

9. Fremgangsmåde ifølge et af kravene 6 til 8,

kendetegnet ved, at

der på basis af den værdi eller funktion af parameteren, som egner sig til standarddrift, bestemmes mindst en tærskelværdi, som udløser en fejlmelding ved standarddrift af svingdrevet, hvis denne over- og/eller underskrides.

- 5 **10.** Fremgangsmåde ifølge et af kravene 5 til 9,
kendetegnet ved, at
læreprocessen gennemføres i en ubelastet tilstand af svingdrevet og/eller en belastet tilstand af svingdrevet.
- 10 **11.** Svingdrev, særligt et roterende indeksbord med en drejeplade (12), som af en motor (22) kan drives til en drejebevægelse om en drejeakse (R), hvor der er tilvejebragt mindst en sensor (24, 24'), som leverer vinkeldata og er forbundet med en styreanordning, til overvågning af en drejebevægelse af motoren (22), af drejepladen og/eller en roterende komponent af en drivlinje anbragt mellem motoren (22) og drejepladen (12), hvor styreanordningen er udformet til udførelse af
- 15 fremgangsmåden ifølge mindst et af de foregående krav.
- 12.** Svingdrev ifølge krav 11,
kendetegnet ved, at
drejepladen har en medbringer, som griber ind i en drevnot på en kurveskive (14), hvor drejepladen
- 20 (12) via kurveskiven (14) kan drives til drejebevægelsen om drejeaksen (R), hvilken på sin side af en motor (22) kan drives til en drejebevægelse om sin længdeakse (R').

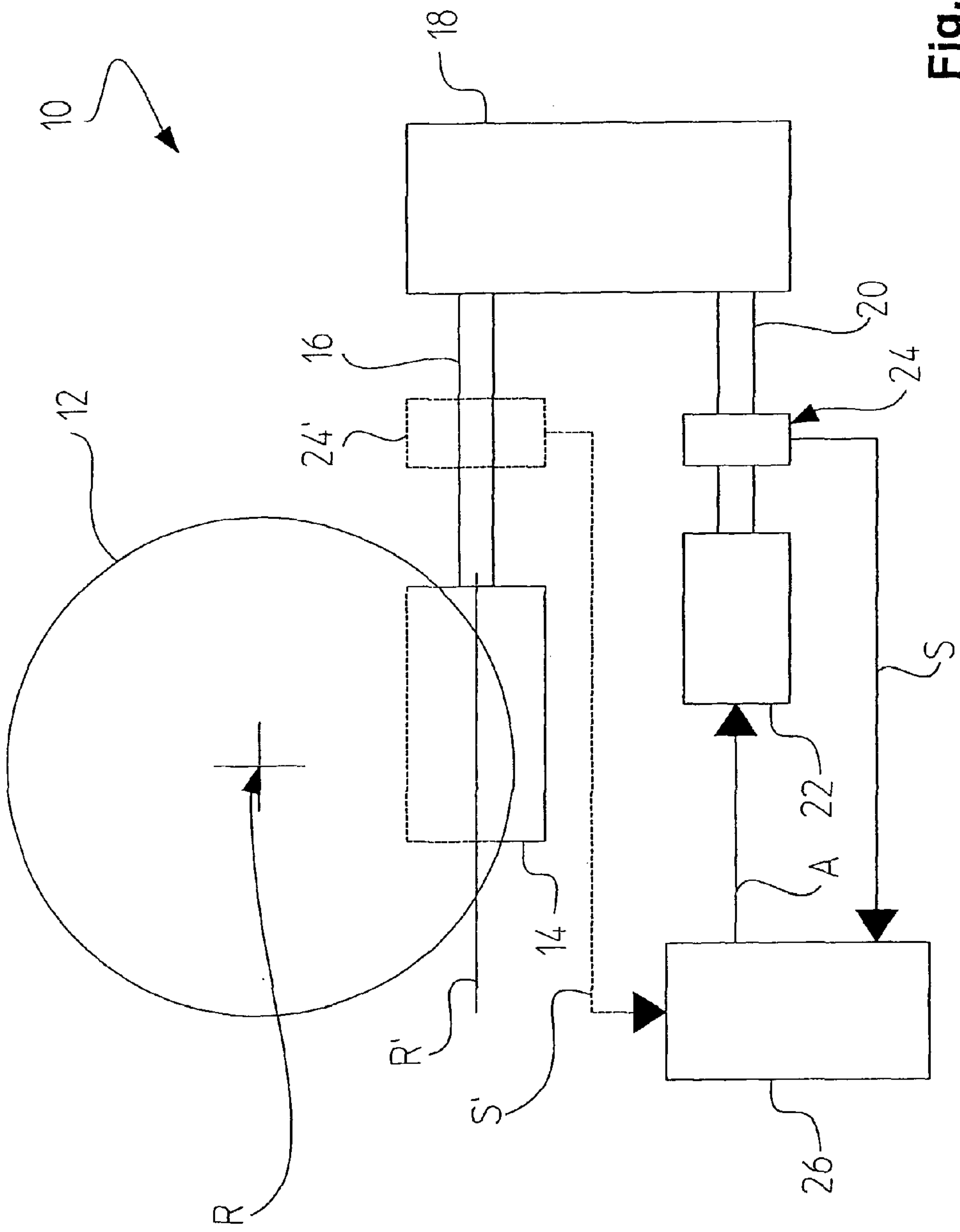


Fig.