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METHOD FOR CONTROLLING A FILTERING DEVICE, METHOD FOR
FILTERING A HIGHLY VISCOUS FLUID, AND FILTERING DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of German Patent Application No. 102023111800.5 filed on May 5, 2024, which is hereby incorporated by reference in its entirety for all purposes as if fully set forth herein.

FIELD OF THE DISCLOSURE

[0002] The disclosed method and device relate to a method for controlling a filtering device for filtering highly viscous fluids, a method for filtering highly viscous fluids, and a filtering device for filtering highly viscous fluids.

BACKGROUND OF THE DISCLOSURE

[0003] Filtering devices of the kind initially specified are generally known from the prior art. One example of such a filtering device is the BKG® HiCon™ R-Type 250 filter. In such filtering devices, impurities retained on the dirt side of the filter element are conveyed to a dirt outlet via a discharge device in the form of a discharge screw. The removed impurities are firstly scraped from the dirt side of the filter element by means of scraper elements of a cleaning unit. The cleaning unit and the discharge screw are driven rotationally via a drive shaft, the discharge rate of the filtering device largely depending on the rotational speed and thus on the driving power. The impurities conveyed to the dirt outlet by means of the discharge screw can then be destroyed or further processed.

[0004] Filtering devices are also known from DE202014101994, DE202019101724, EP3010620, EP2907646 and EP0160782.

[0005] Impurities removed from the melt include organic or inorganic materials such as wood or paper, metals or even non-metallic foreign substances, and polymeric foreign substances such as residues of other plastics.

[0006] With the aim of reducing wear on the cleaning unit, it is desirable to keep the rotational speed of the cleaning unit, particularly its scraper elements, as low as possible. In filtering devices in which the discharge unit is driven jointly with the cleaning unit, this results in equal measure in a lower rotational speed of the discharge unit. However, if the speed of the discharge unit is too low, this can lead to blockages, because the flowability of the highly viscous fluid decreases as the proportion of impurities increases, until flow ultimately becomes impossible and a blockage occurs. Clogging of the filtering device or the discharge unit results in downtimes due to the maintenance work required. Nor may the speed of the discharge unit be too high, however, as discharge losses can occur when the speed of the discharge unit and thus the conveying speed is too high. Discharge losses are understood to mean that the discharge unit discharges not only impurities in the free-flowing mass, but also filtered fluid that is supposed to be discharged on the clean side. Such discharge losses can be detected on the basis of a pressure differential between the inlet and the outlet, for example, or an internal pressure in the filtering device.

[0007] One challenge when controlling a filtering device is therefore to provide a sufficiently high driving power to counteract any blockages, while also preventing any discharge losses. Such control is most done manually at present, by analyzing the free-flowing mass that is discharged. Setting up the filtering device manually and selecting appropriate operating parameters is also a time-consuming process. Machine settings that are set in advance do not allow a response to operational variations in throughput, or even to a surge of impurities. A surge of impurities is understood to mean that the highly viscous fluid to be filtered briefly contains an amount of impurities that is far above average.

SUMMARY OF THE DISCLOSURE

[0008] This problem is addressed by the disclosed method and device, the purpose of which is to specify an alternative method of

controlling a filtering device and an alternative filtering method for a filtering device, as well as a corresponding filtering device for filtering highly viscous fluids. In particular, the purpose of the disclosed method and device is to optimize the operation of a filtering device and in particular of the discharge device in such a way that discharge losses are reduced while at the same time allowing impending blockages in the discharge unit to be counteracted at an early stage.

[0009] In a first aspect, the disclosed method and device achieves the purpose specified above by means of the filtering device according to claim 1. The disclosed method and device proposes a method for controlling a filtering device. Such a filtering device has a filtration unit for removing impurities from a highly viscous fluid, a discharge unit for discharging a free-flowing mass containing the removed impurities and that cooperates with the filtration unit, at least one drive means for driving the filtration unit and/or the discharge unit, and at least one controller. The disclosed method and device proposes that the method comprises the steps of:

- a) monitoring a control variable that characterizes the composition of the free-flowing mass and/or the amount of the impurities from the highly viscous fluid in the region of the filtration unit;
- b) defining a setpoint value that characterizes a composition of the free-flowing mass and/or the amount of the impurities from the highly viscous fluid in the region of the filtration unit and which the control variable should follow,
- c) comparing the control variable with a setpoint value to determine any deviation;
- d) changing a correcting variable according to the determined deviation, wherein the correcting variable characterizes the output power of at least one drive means; and
- e) controlling the drive means with the correcting variable.

[0010] The inventors realized advantageously that the composition of the free-flowing mass conveyed through the discharge unit, just like the amount of impurities from the highly viscous fluid in the region of the filtration unit, provides information about the flow properties of the free-flowing mass on its path through the discharge unit. The output power is understood here to be a variable affecting the volumetric flow rate of discharge. If the free-flowing mass becomes more sluggish because the removed impurities form a high proportion of it, a stronger torque or a stronger driving power of a discharge screw, for example, is needed as a control variable in order to prevent any blockage. In discontinuous discharge units that discharge a defined discharge volume portionwise, it may be necessary to increase the discharge volume, for example. A greater proportion of impurities in the free-flowing mass occurs, for example, when such a discharge screw is operated at very low speeds, for example, or when a surge of impurities occurs. By monitoring the control variable that characterizes such a composition and by changing the correcting variable when a deviation of the control variable from the setpoint value is detected, the composition of the free-flowing mass or the amount of impurities is approximated to a setpoint value that allows continuous discharge without blockages while at the same time preventing or minimizing any undesired discharge losses.

[0011] A control variable is understood here to mean a variable that is to be held at a predefined constant or variable value, the setpoint value.

[0012] A setpoint value, also referred to as a command variable or set point, is a variable that is externally supplied to the control system and which the control variable is to follow.

[0013] A correcting variable is understood here to be an output variable from a controller. The control variable can be influenced across the controlled system by changing the correcting variable. This is done in order to bring the control variable into line with the setpoint value, for

example. The controlled system refers here to a device, a system or the like whose output variable is controlled by changing one or more control variables. The controlled system is understood here to be the entire filtering device, or just the discharge unit. A controller is understood to be a device that can be integrated into a control system or the like and compares the control variable and setpoint value with each other and forms the correcting variable from the difference. A method is thus proposed for automated control of the filtering device, which allows operation to be optimized in such a way that blockages are prevented while counteracting discharge losses and greater wear of the filtering device, which may be due to the driving power of the discharge device or filtration unit being too high.

[0014] Developments of the disclosed method and device are specified in the dependent claims, which develop the concept of the disclosed method and device in respect of advantageous features in connection with the stated purpose, and with regard to further advantages.

[0015] The control variable preferably comprises one or more or all of the following:

- the torque, in particular the output torque, of the at least one drive means;
- the output torque value or torque of a frequency converter associated with the drive means;
- the torque of a drive shaft coupled to the drive means;
- the power input of the drive means;
- the power input of a frequency converter associated with the drive means;
- the current draw of the drive means;
- the current draw of a frequency converter associated with the drive means;
- the pressure differential between a housing inlet and a housing outlet of the filtration unit;

- the difference in weight between the highly viscous fluid to be filtered and the discharged free-flowing mass;

- [0016] the voltage draw of a drive means, in particular of a DC motor;

- [0017] the control pressure of a hydraulic motor;

- [0018] the temperature of the drive means and/or the frequency converter; and

- [0019] the temperature of the free-flowing mass in the region of the discharge unit.

[0020] By monitoring one or more or all of the aforementioned control variables, it is possible to monitor the composition of the free-flowing mass or the proportion of impurities in the region of the filtration unit. For example, the torque of a drive means or of a drive shaft coupled to the drive means increases if the free-flowing mass contains an increasing proportion of impurities. In this case, the flowability of the free-flowing mass is reduced, and the free-flowing mass becomes more sluggish. The torque that needs to be applied in order to discharge the free-flowing mass increases accordingly and is an indicator of the changing composition. An output torque value of a frequency converter associated with the drive means, as well as the power input of the drive means or the frequency converter, likewise allow conclusions to be drawn about a changing composition of the free-flowing mass being conveyed in the region of the discharge unit. When the rotational speed is constant, the torque that needs to be applied or the power input that is necessary is increased when the flowability of the free-flowing mass is reduced. The same relationship also applies to the current draw of the drive means or the frequency converter. Monitoring the pressure differential, as a control variable, between a housing inlet and a housing outlet of the filtering device allows conclusions to be drawn about the amount of impurities in the region of the filtration unit or the composition of the free-flowing mass being conveyed through the discharge unit. If the free-flowing mass

conveyed through the discharge unit contains a high proportion of the filtered fluid, the pressure differential between the housing inlet and the housing outlet increases, because the pressure at the housing outlet falls due to the lower flow rate. The same relationship applies to the difference in weight between the highly viscous fluid to be filtered and the discharged free-flowing mass.

[0021] If the device is driven by a hydraulic motor, the control pressure is also a suitable control variable.

[0022] It is also preferable that the correcting variable comprises one or more or all of the following:

[0023] the output shaft speed of the drive means;

[0024] the output frequency of a frequency converter associated with the drive means;

[0025] the output power of a frequency converter associated with the drive means;

[0026] a rotational speed of a drive shaft coupled to the drive means;

[0027] a position of the discharge unit that determines the discharge volume; and

- a pivot angle of the discharge unit.

[0028] The output shaft speed of the drive means or the output frequency of the frequency converter influence the torque of the drive shaft or the output torque of the drive means and thus allow the composition of the free-flowing mass or the amount of impurities in the region of the filtration unit to be directly influenced. The same applies to the output power of a frequency converter associated with the drive means, or to its output frequency. If an axial piston pump is used as the discharge unit, the pivot angle of the discharge unit can also change the discharge rate or output power and can thus exert an influence on the pressure differential or the difference in weight or also the discharge speed.

[0029] It is preferred that step a) comprises one or more or all of the following substeps:

- capturing the control variable for a predefined measurement interval (Δt_M),
- capturing the control variable with a predefined number of measurement points, preferably within the predefined measurement interval,
- forming a mean value from the control variable captured in the predefined measurement interval and/or with the predefined number of measurement points. The control variable is thus captured for a defined number of measurement points. The number of control variables captured depends, for example, on the measurement period, with the control variable being captured continuously for 30 seconds, for example, or on a predefined number of measurement points per unit of time. In this case, the control variable is captured every five seconds, for example. Forming a mean value from the captured control variables for such a predefined measurement interval or number of measurement points allows the influence of disturbance variables to be reduced.

[0030] It is further preferred that, in step d), the correcting variable is changed step by step with a predefined step size and kept constant for a predefined holding interval. The measurement interval and/or the number of measurement points preferably correlates with the holding interval. Keeping the correcting variable constant for a predefined holding interval takes account of the fact that the influence of the correcting variable on the control variable may be subject to a time delay.

[0031] According to another preferred embodiment, the correcting variable is changed in step d) by a PID controller. A PID controller allows the correcting variable to be adjusted with a delay, so that any delayed influence of the correcting variable on the control variable can be taken into account.

[0032] According to another preferred embodiment, the method further comprises the step of:

[0033] f) defining at least one system variable and/or a system range.

[0034] The system variable preferably comprises one, more or all of the following:

- a minimum threshold value for the control variable, wherein the control variable is not monitored in step a) until the predefined threshold value is exceeded,
- a minimum trigger value for the control variable, wherein at least steps d) and e) are not carried out until the minimum trigger value is exceeded,
- a critical deviation, for the deviation determined in step c), that characterizes an imminent surge of impurities,
- a maximum correcting variable and/or control variable, wherein the correcting variable in step d) is changed in such a way that the maximum correcting variable and/or control variable is not exceeded,
- a start-up correcting variable of the drive means, with which the drive means is controlled when it starts operating.

[0035] The fact that in a start-up mode the control variable initially assumes values below a minimum threshold value and that disturbance variables play a greater role in this range is thus taken into account. This means that influencing the control variable by means of the correcting variable can only be done with a large degree of uncertainty, so it therefore makes little sense in most cases. It thus makes little sense to monitor the control variable when it is in such a low range. Defining a minimum trigger value also ensures that the control variable is monitored as soon as it exceeds the minimum threshold value, but is not changed by the correcting variable. The minimum trigger value is above the minimum threshold value and specifies a value above which it is possible and makes sense to control the control variable by means of the correcting

variable. Defining a critical deviation for the deviation determined in step c) also allows special measures to be taken in the event that the critical deviation characterizes an impending surge in impurities. In this case, the discharge unit can be driven at high speed to clear it of impurities, for example. Clearing is understood to mean driving a discharge screw, for example, at a high speed so that the impurities or free-flowing mass accumulated in the discharge screw are discharged from it at high speed and any blockages are broken up. By defining a maximum correcting variable, the correcting variable in step d) is changed according to the determined deviation in such a way that it is updated with the maximum correcting variable in the event that the correcting variable determined according to the deviation is above the maximum correcting variable.

[0036] Alternatively or additionally, a tolerance range for the deviation determined in step c) is defined as a system range that characterizes a setpoint rate of change of the control variable. A range for changing the control variable is thus identified in which no further increase in the control variable is necessary, for example.

[0037] According to a preferred embodiment, the method further comprises controlling the drive means with a predefined start-up correcting variable. The step is preferably carried out before or at the same time as monitoring the control variable in step a). This means that the start-up correcting variable is defined parallel to monitoring the control variable or even prior to that, and that the drive means is controlled with the start-up correcting variable. The start-up correcting variable defines a correcting variable which allows the filtering device to be started in a start-up mode. By controlling the drive means with the start-up correcting variable, the control variable is adjusted from a value of zero, which the control variable assumes in downtimes, to a control variable that deviates therefrom. Account is taken of the fact that, when operation begins, it is not expedient to monitor the control variable, because it is not yet subject to any

operational influences and in particular is not influenced by changes in the composition of the free-flowing mass.

[0038] Defining the setpoint value in step b) preferably comprises defining a hysteresis range within which a number of setpoint values lie, or that comprises a number of control variables. Providing a hysteresis range allows the influence of disturbance variables such as variations in throughput to be minimized, and the control process to be stabilized. Control is thus performed only within such a range as is actually necessary.

[0039] Alternatively or additionally, defining the setpoint value in step b) comprises defining a setpoint rate of change of the control variable, and in step c) comparing a rate of change of the control variable with the setpoint rate of change. Influencing the control variable by means of the correcting variable in such a way that the change in the control variable corresponds to the setpoint value, namely to a predefined rate of change, allows the control variable to be kept constant at that value.

[0040] It is preferable that the method further comprises storing the control variable monitored in step a) for a predefined storage period. The change in the control variable can thus be tracked over time, and long-term trends can also be identified.

[0041] It is preferred that, if the deviation determined in step c) is outside the hysteresis range or deviates from a predefined setpoint value, the correcting variable is changed in step d) in a short-time duty cycle, and if the deviation determined in step c) is within the hysteresis range or is equal to the setpoint value, operation is in a continuous duty cycle.

[0042] Short-time duty preferably includes a first operating mode in which the correcting variable is increased in step d), in particular is increased step by step, if the deviation determined in step c) is above the hysteresis range or the setpoint value, wherein the correcting variable in the first operating mode is preferably increased in step d) to the maximum correcting variable if the deviation determined in step c) reaches or

exceeds the critical deviation. In the first operating mode, the correcting variable is increased with the aim of preventing operating failures due to a blockage in the filtration unit and/or the discharge unit. For example, a torque indicates, as a control variable above a hysteresis range, that the flowability of the mass to be discharged is becoming increasingly sluggish. This may be due to a surge in impurities, for example. By increasing the speed of the drive means for the discharge unit and preferably also of the filtration unit, as a correcting variable, the discharge speed is temporarily increased, and a greater proportion of the filtered, highly viscous fluid is discharged as well. In addition to increased speed, this proportion also facilitates the discharge of the free-flowing mass in the region of the discharge unit and hence the discharging of the impurities in the surge in impurities. The control variable subsequently stagnates or even falls, so operation can then be optimized, in particular by implementing the second operating mode or a third operating mode.

[0043] Short-time duty preferably includes a second operating mode in which the correcting variable is reduced in step d), in particular is reduced step by step, if the deviation determined in step c) is below the hysteresis range or the reference value and/or a change in the control variable occurring after the first operating mode is carried out within the predefined tolerance range. In the second operating mode, it is possible to reduce a driving power or a rotational speed, for example, with the aim of reducing the discharge losses of a filtering device and in particular its wear and tear. The reduction is preferably made step by step if the determined deviation of the control variable is within the predefined tolerance range or a deviation is below the hysteresis range. For example, the control variable can be the torque of the drive means, and the correcting variable can be the speed of the drive means.

[0044] Continuous duty preferably includes retrieving a change in the correcting variable within a predefined time interval, wherein if the change in correcting variable has been carried out, the correcting variable

is changed in a third operating mode, and if no change in the correcting variable has been carried out, the correcting variable is changed in a fourth operating mode.

[0045] The third operating mode preferably comprises the substeps of:

- defining a pressure differential limit that defines when a critical discharge loss is reached,
- capturing a pressure differential between a housing inlet and a housing outlet of the filtering device, wherein the control variable is a first control variable and the pressure differential is a second control variable, and
- comparing the captured pressure differential with the predefined pressure differential limit,
- reducing the correcting variable if the pressure differential is above the pressure differential limit. However, if the deviation of the torque is within the hysteresis range, operation of the filtering device can be further optimized in the third operating mode. The correcting variable is thus reduced in the third operating mode, preferably step by step, and this procedure is continued until it can be identified that the reduction is having an effect on the control variable. During operation, it is possible that the torque remains constantly within the predefined hysteresis range when a minimum speed is exceeded, but that the speed, as a correcting variable, has been increased further or unnecessarily. The speed is therefore higher than the minimum speed required as a correcting variable, which results in greater wear and possible discharge losses. By operating in the third operating mode, the speed is then reduced step by step and an optimal operating point is determined.

[0046] The hysteresis range is preferably a first hysteresis range. It is further preferred that the fourth operating mode comprises the substeps of:

- defining a second hysteresis range that differs from the first hysteresis range,
- retrieving the stored control variables and the mean values from the memory,
- comparing the stored control variables with the second hysteresis range and determining a future or current deviation of the control variables from the second hysteresis range, and
- increasing the correcting variable if a future or current deviation of the control variables from the second hysteresis range is identified.

[0047] As a second control variable, the pressure differential characterizes, among other things, the amount of impurities in the region of the filtration unit. Increasing contamination of the filter element in the filtration unit causes the amount of impurities in the region of the filtration unit to increase. This increasing contamination causes a gradual long-term increase in the control variable, for example in the torque, because an increasing amount of force is needed to discharge the free-flowing mass from the filtration unit and through the discharge unit. This increase in the control variable is too small to result in a deviation from the first hysteresis range within a measurement interval. By retrieving stored control variables or their mean values, it is possible to observe a long-term trend in the behavior of the control variable and to compare this with a second hysteresis range that is preferably smaller than the first hysteresis range. The correcting variable can then be increased as a consequence, so that the control variable is stabilized despite the increasing level of contamination.

[0048] It is further preferred that the correcting variable is changed in step d) in the first operating mode with a predefined step size, and in the second operating mode with a second predefined step size that differs from the first predefined step size. It is further preferred that the correcting variable is changed in step d) in the third operating mode with a third predefined step size and in the fourth operating mode with a fourth

predefined step size. The first step size and the second step size preferably differ from the third step size and the fourth step size. The first step size is preferably greater than the second step size and/or the third step size and/or the fourth step size. The step size specifies a value by which the correcting variable is changed, whereas the holding period specifies a value for which the correcting variable is kept before it is changed step by step to the next smaller or next greater value. The orders of magnitude by which the correcting variable is changed in the respective step size are preferably predefined and different from each other.

[0049] It is particularly preferred that the control variable is a torque and is monitored in step a) by means of the controller, preferably a controller of the or a frequency converter. Alternatively or additionally, the control variable is a torque and is monitored in step a) at the drive shaft or at a coupling operatively connected to the drive shaft, preferably by means of strain gauges. Monitoring the torque as a control variable by control communication allows simple implementation in the control system, which can be done by the controller. Capturing the torque via strain gauges allows the control variable to be monitored in a purposeful manner.

[0050] In a second aspect, the disclosed method and device achieves the purpose specified above by means of a method according to claim 17. According to the second aspect, the disclosed method and device proposes a method for filtering highly viscous fluids by means of a filtering device, in particular by means of a filtering device according to the third aspect of the disclosed method and device as described below, wherein the filtering device has a filtration unit for removing impurities from a highly viscous fluid, a discharge unit for discharging a free-flowing mass containing the removed impurities and that cooperates with the filtration unit, and at least one drive means for driving the filtration unit and/or the discharge unit. The method comprising the steps of:

a) conveying the highly viscous fluid to be cleaned through the filtration unit and thus removing impurities from the highly viscous fluid;

b) discharging by means of the discharge unit a free-flowing mass containing the removed impurities;

c) driving the filtration unit and/or the discharge unit by means of the at least one drive means;

d) controlling the filtering device by means of the controller according to a method according to the first aspect of the disclosed method and device.

[0051] By controlling the filtering device with a method according to the first aspect of the disclosed method and device, the method for filtering highly viscous fluids utilizes the advantages described above with reference to the first aspect of the disclosed method and device.

Advantages and preferred embodiments of the method for controlling according to the first aspect of the disclosed method and device are also advantages and preferred embodiments of the method for filtering highly viscous fluids according to the second aspect of the disclosed method and device, and vice versa.

[0052] In a third aspect, the disclosed method and device achieves the purpose specified above by means of a filtering device according to claim 18. According to the third aspect, the disclosed method and device proposes a filtering device for filtering highly viscous fluids, comprising: a filtration unit for removing impurities from a highly viscous fluid, a discharge unit for discharging a free-flowing mass containing the removed impurities from the filtering device and that cooperates with the filtration unit, at least one drive means for driving the filtration unit and/or the discharge unit, and a controller for controlling the filtering device, in particular the drive means. The controller is configured to carry out a method according to the first aspect of the disclosed method and device for controlling the filtering device. By configuring the controller, the filtering device utilizes the advantages described above with reference the first aspect of the disclosed method and device. Advantages and preferred embodiments of the first aspect of the disclosed method and device are

therefore also advantages and preferred embodiments of the third aspect of the disclosed method and device, and vice versa.

[0053] The filtration unit and the discharge unit are jointly driven by the drive means. The controller is preferably configured to provide a correcting variable for the at least one drive means. The controller thus determines the correcting variable from the deviation of the control variable from the setpoint value as determined in step c). This correcting variable is used to control the drive directly or indirectly controlling a or the frequency converter, and thus has an influence on the control variable.

[0054] It is further preferred that the drive means is a first drive means which is configured to drive the filtration unit, and that the filtering device also has a second drive means which is configured to drive the discharge unit. The controller is preferably configured to provide a first correcting variable for the first drive means and a second correcting variable for the second drive means. The filtration unit and the discharge unit are each driven independently of the other by their own respective drive means, therefore. The drive means and the discharge unit are each controlled by the controller with a respective correcting variable determined in accordance with step c). It is also possible for a plurality of control variables to be monitored in step a). The first correcting variable is preferably determined by the deviation of a first control variable from a setpoint value, and the second correcting variable is preferably determined by a deviation of the second control variable from a setpoint value. The first correcting variable preferably differs from the second correcting variable.

[0055] It is further preferred that the filtering device also comprises a memory which is associated with the controller and is configured to store and to provide to the controller one or more or all of the following parameters:

- a start-up correcting variable,
- a maximum correcting variable,

- a minimum correcting variable,
- a holding interval,
- a measurement interval,
- a number of measurement points,
- a minimum threshold value,
- a minimum trigger value,
- a tolerance range,
- a critical deviation, and
- a change in the correcting variable.

[0056] Full control and advance definition of all the relevant system parameters is therefore possible.

[0057] According to another preferred embodiment, the filtering device further comprises a display device which is configured to display a current correcting variable in a predefined range of values, wherein the range of values is defined by the minimum correcting variable and/or the maximum correcting variable, and/or is defined as a percentage of the maximum correcting variable. A purposeful display device is thus provided that can be used to track the change in the correcting variable.

[0058] According to a preferred embodiment, the filter element is designed as a sieve drum, and the filtering device also has a cleaning unit having a plurality of scraper members. The sieve drum is designed as a vertical sieve drum, and the cleaning unit is coupled to the drive means and is driven rotationally about a rotational axis. The cleaning unit is alternatively designed as a vertical cleaning unit, and the sieve drum is coupled to the drive means and is driven rotationally about a rotational axis. As a further alternative, the sieve drum and the cleaning unit are driven in opposite directions to each other. A filtering device is thus provided in which a sieve drum and the cleaning unit perform a relative movement in relation to each other. Impurities are removed in this way from the filter element, in this case from a sieve drum.

[0059] The discharge unit preferably has a dirt outlet and a discharge screw which is coupled to the drive means, in particular to the drive shaft, and which is designed to convey the free-flowing mass from the filtration unit towards the dirt outlet.

[0060] According to an alternative embodiment, the discharge unit has a piston pump, in particular an axial piston pump, having at least one piston that is driven linearly by rotation of the drive shaft to perform a stroke action in such a manner that a containment volume is formed sequentially depending on the stroke action of the piston, in which the free-flowing mass is received, and is further reduced to discharge the free-flowing mass from the receiving chamber to a dirt outlet.

[0061] A discharge screw, just as a piston pump, provide purposeful discharge units whose driving power can be influenced by at least one correcting variable. The discharge rate can be increased, for example, by increasing the speed of the axial piston pump or the discharge screw, thus counteracting any surge in impurities by increasing the speed accordingly as a correcting variable.

[0062] The filtering device preferably also comprises a coupling which is operatively connected to the drive shaft and which is fitted with at least one strain gauge for determining a torque of the drive shaft as a control variable. In this way, the torque can be permanently monitored as a control variable by means of strain gauges.

[0063] It is further preferred that the drive means has an electric motor with a frequency converter, the frequency converter being configured to control the speed of the electric motor as a correcting variable. To that end, the frequency converter provides an output frequency, for example. The control variable is also provided in the form of output variable from the frequency converter, in particular an output frequency or an output torque value. The latter is preferably provided at a control interface of the frequency converter. The frequency converter provides a correcting variable or an output variable that correlates with the

correcting variable and thus exerts a direct influence on the control variable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0064] Preferred embodiments of the invention shall now be described with reference to the attached Figures, in which:

[0065] Fig. 1: shows a cross-sectional view of a filtering device for filtering highly viscous fluids, according to a first embodiment of the disclosed method and device,

[0066] Fig. 2: shows a cross-sectional view of a filtering device for filtering highly viscous fluids, according to a second embodiment of the disclosed method and device,

[0067] Fig. 3: shows a first embodiment of a method for operating a filtering device as shown in Fig. 1 and Fig. 2,

[0068] Fig. 4: shows a second embodiment of a method for operating a filtering device as shown in Fig. 1 and Fig. 2,

[0069] Fig. 5: shows a third embodiment of a method for operating a filtering device as shown in Fig. 1 and Fig. 2,

[0070] Fig. 6: shows a fourth embodiment of a method for operating a filtering device as shown in Fig. 1 and Fig. 2,

[0071] Fig. 7a: shows substeps of the third operating mode for a method as shown in Fig. 6;

[0072] Fig. 7b: shows substeps of the fourth operating mode for a method as shown in Fig. 6;

[0073] Fig. 8a: shows a control diagram of the first operating mode;

[0074] Fig. 8b: shows a control diagram of the second operating mode;

[0075] Fig. 8c: shows a control diagram of the third operating mode;

[0076] Fig. 8d: shows a control diagram of the fourth operating mode; and

[0077] Fig. 9: shows a method for filtering highly viscous fluids by means of a filtering device as shown in Fig. 1 or Fig. 2.

DETAILED DESCRIPTION

[0078] The disclosure will now be described with reference to the drawing figures, in which like reference numerals refer to like parts throughout.

[0079] Fig. 1 shows a perspective view of a prior art filtering device 1' for removing impurities 110 from a highly viscous fluid 100 and having a filtration unit 3 with a filter chamber 5.

[0080] Filter housing 3 of filtration unit 3 has a housing inlet 7 for feeding the highly viscous fluid 100 to be cleaned into filter chamber 5, and a housing outlet 9 for conducting the cleaned highly viscous fluid 120 out of filter chamber 5. A filter element 11 for filtering impurities 110 from the highly viscous fluid 100 is accommodated in filter chamber 5.

[0081] Filter element 11 has a "dirt side" 15 where impurities 110 accumulate and where impurities 110 are retained, and a "clean side" 17 where the cleaned highly viscous fluid 120 flows away. The cleaned highly viscous fluid 120 is then conducted to housing outlet 9.

[0082] Filtration unit 3 preferably includes a cleaning unit 57 in the form of a cleaning head having a plurality of scraper members 57A for dislodging impurities 110 that have accumulated on filter element 11, the scraped-off impurities 110 flowing along dirt side 15 towards a discharge unit 18'.

[0083] Discharge unit 18' is configured for metered discharge of the impurities retained on dirt side 15 through a dirt outlet 23'.

[0084] The impurities 110 removed by filter element 11 are then discharged from discharge unit 18' via dirt outlet 23'. A cooled discharge screw 19 which is coupled to a drive shaft 29 and associated with discharge unit 18' is arranged for that purpose in the region of dirt outlet 23'. By means of the cooled discharge screw 19, the impurities 110 removed by discharge unit 18' at filter element 11 are discharged from

filter chamber 5, without being deposited to any significant extent on discharge screw 19. Drive shaft 29 extends in the axial direction and is driven rotationally about a rotational axis A by a drive means 50 of cleaning unit 57, with the motion being transferred to discharge screw 19. Rotational axis A thus extends in the axial direction. The axial direction and the rotational axis of drive shaft 29 are therefore to be understood as synonyms.

[0085] Filtering device 1' further comprises a controller 40 for controlling filtering device 1'. Controller 40 controls a drive means 50 of cleaning unit 57 or a frequency converter 32 which is associated with drive means 50 and configured to provide an output frequency for driving drive means 50. A memory 42 is also associated with controller 40 and is configured to store for a predefined storage period a control variable M that is monitored by controller 40.

[0086] Filtering device 1' further comprises a coupling 34 which is operatively connected to drive shaft 29 and which is fitted with at least one strain gauge 35 for determining a torque of drive shaft 29 as control variable M (cf. Figs. 8a – 8d).

[0087] Filter device 1' also comprises a display device 33 which is configured to display a current correcting variable n (cf. Figs. 8a – 8d) in a predefined range of values, wherein the range of values is defined by the minimum correcting variable and/or the maximum correcting variable, and/or is defined as a percentage of the maximum correcting variable.

[0088] Controller 40 is configured to carry out a method 1000 as shown in Figs. 3 – 7b.

[0089] Fig. 2 shows a filtering device 1 according to the disclosure for removing impurities 110 from a highly viscous fluid 100. Identical or similar components have identical reference signs.

[0090] Filtering device 1 includes a filtration unit 3 having a filter chamber 5, a housing inlet 7 for feeding the highly viscous fluid 100 to be filtered into filter chamber 5 and a housing outlet 9 for conducting the

cleaned highly viscous fluid 120 out of filter chamber 5. A filter element 11 for filtering impurities 110 from highly viscous fluid 100 is accommodated in filter chamber 5.

[0091] Filtering device 1 also includes a discharge unit 18 in fluid communication with filter unit 3, for metered discharge of filtered impurities 110.

[0092] As shown in Fig. 2, filter element 11 is adapted to filter impurities 110 from highly viscous fluid 100 in such a way that impurities 110 are retained on the dirt side 15 of filter element 11, and cleaned highly viscous fluid 120 flows on the clean side 17 towards housing outlet 9.

[0093] The impurities 110 retained on the dirt side 15 are conveyed by means of discharge unit 18 towards a dirt outlet 23 of discharge unit 18 for metered discharge.

[0094] Discharge unit 18 is connected by means of a cleaning port 51 to filtration unit 3. A cleaning port channel 13, which in Fig. 2 is in fluid communication with filter chamber 5 and dirt outlet 23, is formed in cleaning port 51. The conically shaped cleaning port channel 13 opens with a preferably hollow cylindrical section 13A into a matching receiving chamber inlet 38B of transfer element 37.

[0095] A sieve drum 55 having dirt side 15 and clean side 17 is arranged in filter chamber 5. Sieve drum 55 therefore constitutes filter element 11. Filtering device 1 further comprises a cleaning unit, in the form of a cleaning head 57 having a plurality of scraper members 57A, for dislodging impurities 110 that have accumulated on sieve drum 55. These are then conveyed along dirt side 15.

[0096] Discharge unit 18 includes a piston pump 20. Piston pump 20 has at least one and preferably four movably accommodated pistons 25 and a drive mechanism 28. Drive mechanism 28 includes a drive shaft 29 which is rotatably mounted about a rotational axis A and adapted to convert a rotation of drive shaft 29 into a stroke action H of piston 25 along a longitudinal piston axis K. Each of the longitudinal piston axes K is

spaced a distance a from the rotational axis A of drive shaft 29. Drive mechanism 28 further comprises a drive means 30 which is designed here as an electric actuator 30A. Drive means 30 is designed to drive the drive shaft 29 about rotational axis A. The axial direction of drive shaft 29 and the rotational axis of drive shaft 29 are to be understood as synonyms.

[0097] In the embodiment shown, piston pump 20 is an axial piston pump 21 and has a cylinder block 31 which forms, at least in sections, a piston chamber 27 and which is designed to accommodate piston 25. Piston chamber 27 is adapted for selective fluid communication with filter chamber 5 or dirt outlet 23.

[0098] Piston chamber 27 has a workspace 27A, the size of which can be varied depending on stroke action H. Workspace 27A is formed at an end section of piston chamber 27 on the side of cleaning port 51 and is bounded by an end face 25A of piston 25.

[0099] Filtering device 1 further comprises a controller 40 which is configured to control the drive means 50 of cleaning unit 57 and the drive means 30 of the discharge unit. In particular, drive means 50 controls cleaning unit 57 having the cleaning head and scraper members 57a. A memory 42 is also associated with controller 40 and is configured to store for a predefined storage period a control variable M that is monitored by controller 40.

[0100] The controller 40 shown in Fig. 2 is configured to carry out a method according to Figs. 3 – 7b, which shall be described in detail below.

[0101] Fig. 3 shows a method 1000 for controlling a filtering device 1 as shown in Figs. 1 and 2. In a first step 1200, method 1000 comprises monitoring a control variable M (cf. Figs. 8a – 8d) that characterizes the composition of the free-flowing mass and/or an amount x of impurities 110 from the highly viscous fluid 100 in the region of filtration unit 3. In a further step 1300 that can be carried out before the first step 1200 or parallel to the first step, at least one setpoint value M_{setpoint} (cf.

Figs. 8a – 8d) is determined that characterizes the composition of free-flowing mass 140 and/or that characterizes an amount x of impurities 110 from the highly viscous fluid 100 in the region of filtration unit 3 and which control variable M should follow. In a further step 1400, control variable M is compared with setpoint value M_{setpoint} to determine deviation Δ (cf. Figs. 8a – 8d). Variable M can be compared directly or indirectly with setpoint value M_{setpoint} . By this is meant that a rate of change dM (cf. Figs. 8a – 8d) of control variable M is compared, for example, with a setpoint rate of change dM_{setpoint} (cf. Fig. 6).

[0102] In a further step 1500, the method includes changing a correcting variable n (cf. Figs. 8a – 8d) according to the determined deviation Δ , the correcting variable n characterizing the output power of at least one drive means 30, 50.

[0103] In a further step 1600, method 1000 includes controlling drive means 30, 50 by means of correcting variable n . This control can be carried out directly via controller 40 as shown in Figs. 1 and 2, or by controlling frequency converter 32 as shown in Fig. 1, which provides an output frequency or an output torque value for controlling drive means 50.

[0104] Fig. 4 shows a second embodiment of method 1000. The same or similar steps have identical reference signs here, and reference is made to the description of the method according to Fig. 3, with only differences being discussed. The embodiment of method 1000 according to Fig. 4 differs from the first embodiment in that monitoring control variable M , as substep 1210, further comprises capturing a number of control variables M , in particular with a number of measurement points x_n per unit of time t (cf. Figs. 8a – 8d) for a predefined measurement interval Δt_M (cf. Figs. 8a – 8d), and forming a mean value $\bar{M}$ (cf. Figs. 8a – 8d) of control variable M . This means that operational variations are taken into account, and that a change in correcting variable n is only triggered if the mean value $\bar{M}$ of control variable M also deviates from setpoint value M_{setpoint} .

[0105] It is further preferred that the mean value $\bar{M}$ determined in step 1210 is stored in a memory 42 in a further step 1700. Both the monitored control variable M and the mean value $\bar{M}$ can be stored in the memory for a predefined storage period t_s (cf. Figs. 8a – 8d).

[0106] The stored control variables M and mean values $\bar{M}$ are preferably taken into account in the third step 1400 when comparing the monitored control variable M or mean value $\bar{M}$ with the setpoint value M_{setpoint} .

[0107] Fig. 5 shows a third embodiment of method 1000 according to the disclosure. The same or similar steps of the method have identical reference signs here, and to avoid repetitions, reference is made to the description of the method according to Fig. 3, with only differences being discussed below.

[0108] In an upstream step 1100, the method according to Fig. 5 comprises the step of defining at least one system variable S or at least one system range SB . Upstream step 1100 preferably comprises defining 1110 a minimum threshold value $M_{\text{thresh.}}$ (cf. Figs. 8a – 8d) for control variable M , wherein control variable M is not monitored in step 1200 until the predefined threshold value $M_{\text{thresh.}}$ is exceeded. Thus, when the filtering device is started up, the correcting variable is not adjusted immediately due to deviations of control variable M from setpoint value M_{setpoint} . Filtering device 1 can therefore start operation to begin with, and not until control variable M , for example a torque, exceeds the predefined threshold value $M_{\text{thresh.}}$ can method 1000 be continued. Setpoint value M_{setpoint} , which is defined in step 1300, can preferably be stored in predefined form in controller 40 and thus be independent of any exceeding of threshold value $M_{\text{thresh.}}$.

[0109] Upstream step 1100 in method 1000 according to Fig. 5 preferably comprises defining 1120 a minimum trigger value M_A (cf. Figs. 8a – 8d) for control variable M , wherein at least the step of changing the correcting variable in step 1500 and controlling the drive means in step

1600 are not carried out until the minimum trigger value M_A is exceeded. The minimum trigger value M_A may be identical to the minimum threshold value $M_{\text{thresh.}}$ or may be above the minimum threshold value $M_{\text{thresh.}}$. Upstream step 1100 preferably comprises defining 1130 a critical deviation $\Delta_{\text{crit.}}$ (cf. Figs. 8a – 8d) for the deviation Δ determined in step c), which characterizes an impending surge in impurities. If control variable M deviates by this critical deviation $\Delta_{\text{crit.}}$ from a hysteresis range ΔH , which is described with reference to the embodiment shown in Fig. 6 and to which reference is made here, then it is possible in the following step 1500 to make a corresponding change in correcting variable n that counteracts a surge in impurities. Upstream step 1100 preferably also comprises defining 1140 a maximum correcting variable n_{max} and/or control variable M_{max} (cf. Figs. 8a – 8d), wherein correcting variable n is changed in step 1500 in such a way that maximum correcting variable n_{max} and/or control variable M_{max} is not exceeded. Upstream step 1100 preferably also comprises defining 1150 a tolerance range ΔT (cf. Fig. 8a) for the deviation Δ determined in step 1400, which characterizes the setpoint rate of change dM_{setpoint} of the control variable.

[0110] Method 1000 according to Fig. 5 also comprises controlling drive means 30, 50 with a start-up correcting variable n_{start} (cf. Figs. 8a – 8d), as an optional substep 1610 of the last step in the method, which relates to controlling drive means 30, 50.

[0111] Fig. 6 shows a fourth embodiment of method 1000 according to the disclosure. The same or similar steps of the method have identical reference signs here, and reference is made to the description of Fig. 3, with only differences between the two embodiments being discussed below in order to avoid repetitions.

[0112] The monitoring performed in step 1200 further comprises capturing a number of control variables M , in particular with a number of measurement points x_n per unit of time t for a predefined measurement interval Δt_M and forming a mean value $\bar{M}$ of control variable M . This means

that operational variations are taken into account, and that a change in correcting variable n is only triggered if the mean value $\bar{M}$ of the control variable deviates from the setpoint value. It is further preferred that the mean values $\bar{M}$ determined in step 1210 are stored in a memory 42 in a further step 1700. Both the monitored control variable M and the mean value $\bar{M}$ can be stored in memory 42 for a predefined storage period t_s .

[0113] Here, the step of defining the setpoint value in step 1300 further comprises, as substep 1310, defining a hysteresis range ΔH (cf. Figs. 8a – 8d) within which a number of setpoint values M lie. Determining hysteresis range ΔH takes account of the fact that control variable M is subject to operational variations and that it makes more sense to use a number of values within hysteresis range ΔH as setpoint value M_{setpoint} than a one specific value.

[0114] Alternatively or additionally, determining the setpoint value in step 1300 comprises the defining 1320 a setpoint rate of change dM_{setpoint} of control variable n , and in step c) a rate of change dM of control variable n is compared with the setpoint rate of change dM_{setpoint} .

[0115] In the event that the determined deviation Δ is outside hysteresis range ΔH , the comparing of control variable M with setpoint value M_{setpoint} in step 1400 is followed, in step 1500-BK in method 1000 according to Fig. 6, by changing correcting variable n in accordance with short-time duty cycle BK. If, however, the determined deviation Δ is within hysteresis range ΔH , correcting variable n is changed in step 1500-BL in accordance with continuous duty cycle BL.

[0116] The short-time duty cycle BK comprises, as first substep 1510-BK, comparing the deviation with the hysteresis range and/or the setpoint value, and performing a first operating mode B1 if the deviation is below the hysteresis range and/or the setpoint value. In the first operating mode B1, correcting variable n is increased, in particular step by step, if the determined deviation is above hysteresis range ΔH . It is further preferred that correcting variable n is preferably increased in the first

operating mode B1 to a maximum correcting variable $n_{\max}$ if the determined deviation reaches or exceeds the critical deviation ΔM_{crit} . The first operating mode is shown in detail in Fig. 8a, and reference is made accordingly to the following description.

[0117] The short-time duty cycle BK also comprises a second operating mode B2, which is performed if the deviation is above the hysteresis range and/or the setpoint value. In the second operating mode B2, the correcting variable is reduced, in particular step by step, if the determined deviation is below hysteresis range ΔH and/or a change in the control variable occurring after performing the first operating mode B1 is within the predefined tolerance range ΔT .

[0118] The continuous duty cycle BL comprises a first substep 1510-BL in which a change in correcting variable Δn is retrieved (cf. Figs. 8a – 8d). If a change in correcting variable Δn has been carried out within a predefined time interval Δt before retrieval in step 1510-BL, correcting variable n is changed in a third operating mode B3 in the fourth step 1500. If no change in correcting variable Δn has been carried out, a fourth operating mode B4 is preferably performed.

[0119] The third operating mode B3 with preferred substeps is shown in Fig. 7a. The aim of the third operating mode B3 is the optimize operation, and this can be carried out if control variable M has settled within hysteresis range ΔH . The third operating mode B3 comprises, as a first substep 1520-B3, defining a pressure differential limit $\Delta p_{\max}$ which defines when a critical discharge loss has been reached. The third operating mode B3 further comprises, in a further substep 1530-B3, capturing pressure differential Δp and finally, in a last substep 1540-B3, comparing the captured pressure differential with the predefined pressure differential limit. If the captured pressure differential differs from the pressure differential limit and the captured pressure differential does not exceed the latter, then step 1550-B3 of reducing correcting variable n is

carried out in the third operating mode B3. This minimizes discharge losses in the long term.

[0120] The fourth operating mode B4 with individual substeps is shown in Fig. 7b. The fourth operating mode B4 is aimed at detecting long-term contamination of the filter and at stabilizing control variable M in the long term by raising correcting variable n. In a first substep 1520-B4, the fourth operating mode B4 comprises defining a second hysteresis range $\Delta H2$ which differs from the first hysteresis range ΔH previously described. In a further substep 1530-B4, the fourth operating mode B4 comprises retrieving the stored control variables M and the mean values $\bar{M}$ of control variable M from memory 42 and comparing 1540-B4 the stored control variables M with the second hysteresis range $\Delta H2$ to determine a future or current deviation of control variables M from the second hysteresis range $\Delta H2$. If such a deviation is identified, the fourth operating mode B4 comprises increasing correcting variable n in a fourth substep 1550-B4. A control variable M leaving the second hysteresis range in the long term, for example a torque M, can be counteracted in this way by increasing correcting variable n at an early stage if filter contamination is increasing. Blockages can be efficaciously counteracted in this manner.

[0121] Figs. 8a – 8d show the first operating mode B1, the second operating mode B2, the third operating mode B3 and the fourth operating mode B4. Correcting variable n is changed step by step here with a step size S1 in the first operating mode, a step size S2 in the second operating mode B2, a third step size S3 in the third operating mode B3 and a fourth step size S4 in the fourth operating mode B4. At least step size S1, S2 in first and second operating mode B1, B2 differs from the third and fourth step size S3, S4 in the third and fourth operating mode B3, B4. After the step-by-step change, correcting variable n is held constant for a predefined holding period H1, H2, H3, H4 (cf. Figs. 8a – 8d), before a new change by the respective step size S1, S2, S3, S4 is carried out.

[0122] The second operating mode B2 according to Fig. 8b preferably follows on from the first operating mode B1 according to Fig. 8a.

[0123] As shown in Fig. 8c, in particular, control variable M is not constant, but fluctuates within hysteresis range ΔH . If there is such a constant control variable M within hysteresis range ΔH , reducing correcting variable n step by step in the third operating mode allows operation to be optimized in such a way that lower speeds counteract wear of the filtering device and prevent discharge losses.

[0124] In this case, the change ΔM in control variable M in Fig. 8d is not outside the first hysteresis range ΔH . However, it can be seen that the control variable leaves the second hysteresis range ΔH_2 in the long term. By increasing correcting variable n step by step, it is possible in this way to ensure trouble-free operation in the long term if there is increasing filter contamination.

[0125] Fig. 9 shows a method 2000 for filtering highly viscous fluids 100 by means of a filtering device 1 as shown in Figs. 1 and 2. In a first step 2100, the method comprises conveying the highly viscous fluid 100 to be cleaned through filtration unit 3 and thus removing impurities 110 from the highly viscous fluid. In a second step 2200, method 2000 comprises discharging a free-flowing mass 140 containing the removed impurities 110 by means of discharge unit 18. In a third step 2300, method 2000 comprises driving filtration unit 3 and/or discharge unit 18 by means of the at least one drive means 30, 50. Finally, in a fourth step 2400, method 2000 comprises controlling filtering device 1 by means of controller 40 in accordance with a method as shown in Figs. 3 – 7b.

[0126] The many features and advantages of the disclosure are apparent from the detailed specification, and, thus, it is intended by the appended claims to cover all such features and advantages of the disclosure which fall within the true spirit and scope of the disclosure. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the disclosure to the exact

construction and operation illustrated and described, and, accordingly, all suitable modifications and equivalents may be resorted to that fall within the scope of the disclosure.

[0127] List of reference signs:

- 1, 1' Filtering device
- 3 Filtration unit
- 5 Filter chamber
- 7 Housing inlet
- 9 Housing outlet
- 11 Filter element
- 13 Cleaning connection channel
- 13A Cylindrical section
- 15 Dirt side
- 17 Clean side
- 18, 18' Discharge unit
- 19 Discharge screw
- 20 Piston pump
- 21 Axial piston pump
- 23 Dirt outlet
- 23' Dirt outlet
- 25 Piston
- 25A End face
- 27 Piston chamber
- 27A Workspace
- 28 Drive mechanism
- 28A Pivot angle actuator
- 29 Drive shaft
- 30 Drive means
- 30A Actuator
- 31 Cylinder block
- 32 Frequency converter

- 33 Display device
- 34 Coupling
- 35 Strain gauge
- 37 Transfer element
- 38B Receiving chamber inlet
- 40 Controller
- 42 Memory
- 50 Cleaning system drive means
- 51 Cleaning port
- 55 Sieve drum
- 57 Cleaning system
- 57A Scraper members
- 100 Highly viscous fluid
- 110 Impurities
- 120 Cleaned highly viscous fluid
- 140 Free-flowing mass
- A Rotational axis
- A' Pivoted rotational axis
- α Pivot angle
- K Longitudinal piston axis
- 1000 Method for controlling
- 1100 Defining a system variable and/or a system range
- 1110 Defining a minimum threshold value
- 1120 Defining a minimum trigger value
- 1130 Defining a critical deviation
- 1140 Defining a maximum correcting variable
- 1150 Defining a tolerance range
- 1200 Monitoring a control variable
- 1210 Determining a mean value
- 1300 Defining a setpoint value
- 1310 Defining a hysteresis range

- 1320 Defining a setpoint rate of change
- 1400 Comparing the setpoint value with the control variable
- 1500 Changing the correcting variable
- 1510-BK Comparing the deviation with the hysteresis range
- 1510-BL Retrieving a change in the correcting variable
- 1520-B3 Defining a pressure differential limit
- 1530-B3 Capturing the pressure differential
- 1540-B3 Comparing the captured pressure differential with the predefined pressure differential limit
- 1520-B4 Defining a second hysteresis range
- 1530-B4 Retrieving the stored control variables
- 1540-B4 Comparing the stored control variables with the second hysteresis range
- 1600 Controlling the drive means with the correcting variable
- 1610 Controlling the drive means with a start-up correcting variable
- 2000 Method for filtering
- 2100 Conveying the highly viscous fluid to be cleaned
- 2200 Discharging a free-flowing mass
- 2300 Driving the filtration unit
- 2400 Controlling the filtering device
- x Amount
- M_{setpoint} setpoint value
- M Control variable
- Δ Deviation
- ΔT Tolerance range
- dM Rate of change
- dM_{setpoint} Setpoint rate of change
- n Correcting variable
- x_n Measurement points
- t Time

Δt_M Measurement interval
 $\bar{M}$ Mean value
 n_{start} Start-up correcting variable
 t_s Storage period
 S System variable
 SB System range
 M_T Trigger value
 $M_{thresh.}$ Threshold value
 $\Delta_{crit.}$ Critical deviation
 $n_{max.}$ Maximum correcting variable
 $M_{max.}$ Maximum control variable
 ΔH (First) hysteresis range
 ΔH_2 Second hysteresis range
 BL Continuous duty cycle
 BK Short-time duty cycle
 $B1$ First operating mode
 $B2$ Second operating mode
 $B3$ Third operating mode
 $B4$ Fourth operating mode
 $S1$ First step size
 $S2$ Second step size
 $S3$ Third step size
 $S4$ Fourth step size
 $H1$ First holding period
 $H2$ Second holding period
 $H3$ Third holding period
 $H4$ Fourth holding period

Claims

1. A method (1000) for controlling a filtering device (1) for filtering highly viscous fluids (100), wherein the filtering device (1) has a filtration unit (3) for removing impurities (110) from a highly viscous fluid (100), a discharge unit (18) for discharging a free-flowing mass (140) containing the removed impurities (110) and that cooperates with the filtration unit (3), at least one drive means (30, 50) for driving the filtration unit (3), and/or the discharge unit (18), and at least one controller (40), and wherein the method (1000) comprises the steps of:

a) monitoring a control variable that characterizes a composition of the free-flowing mass (140) and/or an amount (x) of the impurities (110) from the highly viscous fluid (100) in a region of the filtration unit (3);

b) defining a setpoint value that characterizes a composition of the free-flowing mass (140) and/or the amount (x) of the impurities (110) from the highly viscous fluid (100) in the region of the filtration unit (3) and which the control variable should follow;

c) comparing the control variable with a setpoint value to determine any deviation;

d) changing a correcting variable according to the determined deviation, wherein the correcting variable characterizes an output power of at least one drive means (30, 50); and

e) controlling the drive means (30, 50) with the correcting variable.

2. The method (1000) according to claim 1,
wherein the control variable comprises one or more or all of the following:

a torque, in particular an output torque, of the at least one drive means (30, 50);

the output torque value of a frequency converter (32) associated with the drive means (30, 50);

- the torque of a drive shaft (29) coupled to the drive means (30, 50);
- the power input of the drive means (30, 50);
- the power input of a frequency converter (32) associated with the drive means (30, 50);
- a current draw of the drive means (30, 50);
- a current draw of a frequency converter (32) associated with the drive means (30, 50);
- a pressure differential between a housing inlet (7) and a housing outlet (9) of the filtration unit (3);
- the difference in weight between the highly viscous fluid (100) to be filtered and the discharged free-flowing mass (140);
- a voltage draw of a drive means (30, 50), in particular of a DC motor;
- a control pressure of a hydraulic motor;
- a temperature of the drive means; and/or
- a temperature of the free-flowing mass in the region of the discharge unit.

3. The method (1000) according to claim 1 or 2, wherein the correcting variable comprises one or more or all of the following:

- an output shaft speed of the drive means (30, 50);
- an output frequency of a frequency converter (32) associated with the drive means (30, 50);
- the output power of a frequency converter (32) associated with the drive means (30, 50);
- the speed of a drive shaft (29) coupled to the drive means (30, 50);
- and/or
- a pivot angle of the discharge unit (18).

4. The method (1000) according to any one of the preceding claims,
wherein the monitoring of the control variable in step a) comprises one or more or all of the following substeps:
capturing (1220) the control variable for a predefined measurement interval (Δt_M),
capturing (1230) the control variable with a predefined number of measurement points, preferably within the predefined measurement interval (Δt_M), and
forming (1210) a mean value from the control variable captured in the predefined measurement interval (Δt_M) and/or with the predefined number of measurement points.
5. The method (1000) according to any one of the preceding claims,
wherein the correcting variable in step d) is changed step by step with a predefined step size (S1, S2, S3, S4) and is kept constant for a predefined holding interval (H1, H2, H3, H4), and
wherein the measurement interval (Δt_M) and/or the number of measurement points (y) correlate with the holding interval (H1, H2, H3, H4).
6. The method (1000) according to any one of the preceding claims, further comprising the step of:
defining (1100) at least one system variable and/or a system range, wherein the system variable comprises one or more or all of the following:
a minimum threshold value for the control variable, wherein the control variable is not monitored (1110) in step a) until a predefined threshold value is exceeded,

a minimum trigger value for the control variable, wherein at least steps d) and e) are not carried out until the minimum trigger value is exceeded (1120),

a critical deviation, for the deviation determined in step c), that characterizes an imminent surge of impurities (1130),

a maximum correcting variable and/or control variable, wherein the correcting variable in step d) is changed in such a way that the maximum correcting variable and/or control variable is not exceeded (1140),

a start-up correcting variable (n_{start}) of the drive means (30, 50), with which the drive means (30, 50) is controlled when it starts operating, and/or

wherein a tolerance range for the deviation determined in step c) is defined (1150) as a system range that characterizes a setpoint rate of change (dM_{setpoint}) of the control variable.

7. The method (1000) according to any one of the preceding claims,

wherein defining the setpoint value in step b) comprises at least one of the following steps:

defining a (1310) hysteresis range that comprises a number of setpoint values, and/or

defining (1320) a setpoint rate of change (dM_{setpoint}) of the control variable (n), and in step c) comparing a rate of change (dM) of the control variable (M) with the setpoint rate of change (dM_{setpoint}).

8. The method (1000) according to claim 7,

wherein, if the deviation determined in step c) is outside the hysteresis range, the correcting variable is changed (1420) in step d) in a short-time duty cycle (BK), and if the deviation determined in step c) is within the hysteresis range, operation is in a continuous duty cycle (BL).

9. The method (1000) according to claim 8,
wherein short-time duty includes a first operating mode (B1) in which the correcting variable is increased in step d), in particular is increased step by step, if the deviation determined in step c) is above the hysteresis range, wherein the correcting variable in the first operating mode is preferably increased in step d) to the maximum correcting variable if the deviation determined in step c) reaches or exceeds a critical deviation, and

short-time duty includes a second operating mode (B2) in which the correcting variable is reduced in step d), in particular is reduced step by step, if the deviation determined in step c) is below the hysteresis range and/or a change in the control variable occurring after performing the first operating mode (B1) is within a predefined tolerance range.

10. The method (1000) according to any one of the preceding claims, further comprising the step of:

storing (1700) the monitored control variable for a predefined storage period.

11. The method (1000) according to claim 8, 9 or 10, wherein continuous duty (BL) includes retrieving a change in the correcting variable (Δn) within a predefined time interval (Δt),

wherein if the change in correcting variable (Δn) has been carried out, the correcting variable (n) is changed in a third operating mode (B3), and

if no change in the correcting variable (Δn) has been carried out, the correcting variable (n) is changed in a fourth operating mode (B4).

12. The method (1000) according to claim 11,

wherein the third operating mode (B3) comprises the steps of:

defining (1520-B3) a pressure differential limit ($\Delta p_{\max}$) that defines when a critical discharge loss is reached,

capturing (1530-B3) a pressure differential (Δp) between a housing inlet (7) and a housing outlet (9) of the filtering device (1), wherein the control variable is a first control variable and the pressure differential is a second control variable, and

comparing (1540-B3) the captured pressure differential (Δp) with a predefined pressure differential limit ($\Delta p_{\max}$),

reducing (1550-B3) the correcting variable (n) if the pressure differential (Δp) is above the pressure differential limit ($\Delta p_{\max}$).

13. The method (1000) according to claim 11 or 12,

wherein the hysteresis range (ΔH) is a first hysteresis range (ΔH) and the fourth operating mode (B4) comprises:

defining (1520-B4) a second hysteresis range ($\Delta H2$) that differs from the first hysteresis range (ΔH),

retrieving (1530-B4) the stored control variables (M) and the mean values ($\bar{M}$) from a memory (42),

comparing (1540-B4) the stored control variables (M) with the second hysteresis range ($\Delta H2$) and determining a future or current deviation (Δ') of the control variables (M) from the second hysteresis range ($\Delta H2$), and

increasing the correcting variable (n) if a future or current deviation (Δ') of the control variables (M) from the second hysteresis range ($\Delta H2$) is identified.

14. The method (1000) according to any one of claims 11 to 13,

wherein the correcting variable is changed in step d) in the first operating mode with a first predefined step size and in the second operating mode with a second predefined step size that differs from the

first predefined step size, and the first step size is preferably smaller than the second step size.

15. The method (1000) according to claim 14,
wherein the correcting variable is changed in step d) in the third operating mode (B3) with a third predefined step size (S3) and in the fourth operating mode (B4) with a fourth predefined step size (S4), wherein the third step size (S3) and the fourth step size (S4) differ from and in particular are smaller than the first step size (S1) and the second step size (S2).

16. The method (1000) according to any one of the preceding claims,
wherein the control variable is a torque and is monitored in step a) by means of the controller (40), preferably by a controller of the frequency converter (32), and/or
wherein the control variable is a torque and is monitored in step a) at the drive shaft (30) or at a coupling (34) operatively connected to the drive shaft, preferably by means of strain gauges (35).

17. A method (1000) for filtering highly viscous fluids (100) by means of a filtering device (1), in particular by means of a filtering device according to at least one of the following claims,
wherein the filtering device (1) has a filtration unit (3) for removing impurities (110) from a highly viscous fluid (100), a discharge unit (18) for discharging a free-flowing mass (140) containing the removed impurities (110) and that cooperates with the filtration unit (3), at least one drive means (30, 50) for driving the filtration unit (3), and/or the discharge unit (18), and
wherein the method (1000) comprises the steps of:

conveying the highly viscous fluid (100) to be cleaned through the filtration unit (3) and thus removing impurities (110) from the highly viscous fluid (100);

discharging by means of the discharge unit (18) a free-flowing mass (140) containing the removed impurities (110);

driving the filtration unit (3) and/or the discharge unit (18) by means of the at least one drive means (30, 50); and

controlling the filtering device (1) by means of the controller according to a method according to at least one of the preceding claims 1 to 16.

18. A filtering device (1) for filtering highly viscous fluids (100), comprising:

a filtration unit (3) for removing impurities (110) from a highly viscous fluid (100),

a discharge unit (18) for discharging a free-flowing mass (140) containing the removed impurities (110) from the filtering device (1) and that cooperates with the filtration unit (3),

at least one drive means (30, 50) for driving the filtration unit (3) and/or the discharge unit (18), and

a controller (40) for controlling the filtering device (1), in particular the drive means (30, 50),

wherein the controller (40) is configured to carry out a method (1000) according to at least one of the preceding claims for controlling the filtering device (1).

19. The filtering device (1) according to claim 18,

wherein the filtration unit (3) and the discharge unit (18) are jointly driven by the drive means (30), and

wherein the controller (40) is configured to provide a correcting variable for the drive means.

20. The filtering device (1) according to claim 19,
wherein the drive means (30) is a first drive means which is configured to drive the filtration unit (3), and the filtering device (1) has a second drive means (50) which is configured to drive the discharge unit (18), and

wherein the controller (40) is configured to provide a first correcting variable (n) for the first drive means (30) and a second correcting variable (n) for the second drive means (50).

21. The filtering device (1) according to any one of claims 18 to 20, further comprising:

a memory (42) which is associated with the controller (40) and is configured to store and to provide to the controller (40) one, more or all of the following system variables:

- a start-up correcting variable,
- a maximum correcting variable,
- a minimum correcting variable,
- a holding interval,
- a measurement interval (Δt_M),
- a number of measurement points,
- a minimum threshold value,
- a minimum trigger value,
- a tolerance range,
- a critical deviation, and/or
- a change in the correcting variable.

22. The filtering device (1) according to any one of claims 18 to 21, further comprising:

a display device (33) configured to display a current correcting variable in a predefined range of values, wherein the range of values is defined by the minimum correcting variable (n_{min}) and/or the maximum

correcting variable ($n_{\max}$), and/or is defined as a percentage of the maximum correcting variable.

23. The filtering device (1) according to any one of claims 18 to 22, wherein a filter element (11) is designed as a sieve drum (55), and the filtering device (3) also has a cleaning unit (57) having a plurality of scraper members (57A),

wherein the sieve drum (55) is designed as a vertical sieve drum, and the cleaning unit (57) is coupled to the drive means (30, 50) and is driven rotationally about a rotational axis (A), or

wherein the cleaning unit (57) is designed as a vertical cleaning unit (57), and the sieve drum (55) is coupled to the drive means (30, 50) and driven rotationally about a rotational axis (A).

24. The filtering device (1) according to any one of claims 18 to 23, wherein the discharge unit (18) has a dirt outlet (23) and a discharge screw (19) which is coupled to the drive means (30, 50), in particular to a drive shaft (29), and which is designed to convey the free-flowing mass (140) from the filtration unit (3) towards the dirt outlet (23), or

wherein the discharge unit (18) has a piston pump, in particular an axial piston pump, having at least one piston that is driven linearly by rotation of the drive shaft (29) to perform a stroke action in such a manner that a containment volume is formed sequentially depending on the stroke action of the piston, in which the free-flowing mass is received, and is further reduced to discharge the free-flowing mass from a receiving chamber to a dirt outlet.

25. The filtering device (1) according to any one of claims 18 to 24, further comprising:

a coupling (34) which is operatively connected to the drive shaft (29) and which is fitted with at least one strain gauge (35) for determining a torque of the drive shaft (29) as a control variable.

26. The filtering device (1) according to any one of claims 18 to 25, wherein the drive means (30, 50) comprises an electric motor having a frequency converter (32), the frequency converter (32) being configured to control a speed of the electric motor, and wherein the control variable is provided by the frequency converter (32), in particular by a control interface (33) of the frequency converter (32).

27. A method for controlling a filtering device for filtering highly viscous fluids, wherein the filtering device has a filtration unit for removing impurities from a highly viscous fluid, a discharge unit for discharging a free-flowing mass containing the removed impurities and that cooperates with the filtration unit, at least one drive means for driving the filtration unit, and/or the discharge unit, and at least one controller, and wherein the method comprises the steps of:

a) monitoring a control variable that characterizes a composition of the free-flowing mass and/or an amount (x) of the impurities from the highly viscous fluid in a region of the filtration unit;

b) defining a setpoint value that characterizes a composition of the free-flowing mass and/or the amount (x) of the impurities from the highly viscous fluid in the region of the filtration unit and which the control variable should follow;

c) comparing the control variable with a setpoint value to determine any deviation;

d) changing a correcting variable according to the determined deviation, wherein the correcting variable characterizes an output power of at least one drive means; and

e) controlling the drive means with the correcting variable.

28. The method according to claim 27,
wherein the control variable comprises one or more or all of the following:
a torque, in particular an output torque, of the at least one drive means;
the output torque value of a frequency converter associated with the drive means;
the torque of a drive shaft coupled to the drive means;
the power input of the drive means;
the power input of a frequency converter associated with the drive means;
a current draw of the drive means;
a current draw of a frequency converter associated with the drive means;
a pressure differential between a housing inlet and a housing outlet of the filtration unit;
the difference in weight between the highly viscous fluid to be filtered and the discharged free-flowing mass;
a voltage draw of a drive means, in particular of a DC motor;
a control pressure of a hydraulic motor;
a temperature of the drive means; and/or
a temperature of the free-flowing mass in the region of the discharge unit.

29. The method according to claim 27,
wherein the correcting variable comprises one or more or all of the following:
an output shaft speed of the drive means;
an output frequency of a frequency converter associated with the drive means;

the output power of a frequency converter associated with the drive means;

the speed of a drive shaft coupled to the drive means; and/or
a pivot angle of the discharge unit.

30. The method according to claim 27,

wherein the monitoring of the control variable in step a) comprises one or more or all of the following substeps:

capturing the control variable for a predefined measurement interval (Δt_M),

capturing the control variable with a predefined number of measurement points, preferably within the predefined measurement interval (Δt_M), and

forming a mean value from the control variable captured in the predefined measurement interval (Δt_M) and/or with the predefined number of measurement points.

31. The method according to claim 30,

wherein the correcting variable in step d) is changed step by step with a predefined step size (S1, S2, S3, S4) and is kept constant for a predefined holding interval (H1, H2, H3, H4), and

wherein the predefined measurement interval (Δt_M) and/or the predefined number of measurement points (y) correlate with the holding interval (H1, H2, H3, H4).

32. The method according to claim 27, further comprising the step of:

defining at least one system variable and/or a system range,
wherein the system variable comprises one or more or all of the following:

a minimum threshold value for the control variable, wherein the control variable is not monitored in step a) until a predefined threshold value is exceeded,

a minimum trigger value for the control variable, wherein at least steps d) and e) are not carried out until the minimum trigger value is exceeded,

a critical deviation, for the deviation determined in step c), that characterizes an imminent surge of impurities,

a maximum correcting variable and/or control variable, wherein the correcting variable in step d) is changed in such a way that the maximum correcting variable and/or control variable is not exceeded,

a start-up correcting variable (n_{start}) of the drive means, with which the drive means is controlled when it starts operating, and/or

wherein a tolerance range for the deviation determined in step c) is defined as a system range that characterizes a setpoint rate of change (dM_{setpoint}) of the control variable.

33. The method according to claim 27,

wherein defining the setpoint value in step b) comprises at least one of the following steps:

defining a hysteresis range that comprises a number of setpoint values, and/or

defining a setpoint rate of change (dM_{setpoint}) of the control variable (n), and in step c) comparing a rate of change (dM) of the control variable (M) with the setpoint rate of change (dM_{setpoint}).

34. The method according to claim 33,

wherein, if the deviation determined in step c) is outside the hysteresis range, the correcting variable is changed in step d) in a short-time duty cycle (BK), and if the deviation determined in step c) is within the hysteresis range, operation is in a continuous duty cycle (BL).

35. The method according to claim 34,

wherein short-time duty includes a first operating mode (B1) in which the correcting variable is increased in step d), in particular is increased step by step, if the deviation determined in step c) is above the hysteresis range, wherein the correcting variable in the first operating mode is preferably increased in step d) to the maximum correcting variable if the deviation determined in step c) reaches or exceeds a critical deviation, and

short-time duty includes a second operating mode (B2) in which the correcting variable is reduced in step d), in particular is reduced step by step, if the deviation determined in step c) is below the hysteresis range and/or a change in the control variable occurring after performing the first operating mode (B1) is within a predefined tolerance range.

36. The method according to claim 27, further comprising the step of:

storing the monitored control variable for a predefined storage period.

37. The method according to claim 35, wherein continuous duty (BL) includes retrieving a change in the correcting variable (Δn) within a predefined time interval (Δt),

wherein if the change in correcting variable (Δn) has been carried out, the correcting variable (n) is changed in a third operating mode (B3), and

if no change in the correcting variable (Δn) has been carried out, the correcting variable (n) is changed in a fourth operating mode (B4).

38. The method according to claim 37,

wherein the third operating mode (B3) comprises the steps of:

defining a pressure differential limit ($\Delta p_{\max}$) that defines when a critical discharge loss is reached,

capturing a pressure differential (Δp) between a housing inlet and a housing outlet of the filtering device, wherein the control variable is a first control variable and the pressure differential is a second control variable, and

comparing the captured pressure differential (Δp) with a predefined pressure differential limit ($\Delta p_{\max}$),

reducing the correcting variable (n) if the pressure differential (Δp) is above the pressure differential limit ($\Delta p_{\max}$).

39. The method according to claim 37,

wherein the hysteresis range (ΔH) is a first hysteresis range (ΔH) and the fourth operating mode (B4) comprises:

defining a second hysteresis range (ΔH_2) that differs from the first hysteresis range (ΔH),

retrieving a stored control variables (M) and the mean values ($\bar{M}$) from a memory,

comparing the stored control variables (M) with the second hysteresis range (ΔH_2) and determining a future or current deviation (Δ') of control variables (M) from the second hysteresis range (ΔH_2), and

increasing the correcting variable (n) if a future or current deviation (Δ') of the control variables (M) from the second hysteresis range (ΔH_2) is identified.

40. The method according to any one of claim 37,

wherein the correcting variable is changed in step d) in the first operating mode with a first predefined step size and in the second operating mode with a second predefined step size that differs from the first predefined step size, and the first step size is preferably smaller than the second step size.

41. The method according to claim 40,
wherein the correcting variable is changed in step d) in the third operating mode (B3) with a third predefined step size (S3) and in the fourth operating mode (B4) with a fourth predefined step size (S4), wherein the third step size (S3) and the fourth step size (S4) differ from and in particular are smaller than the first step size (S1) and the second step size (S2).

42. The method according to claim 28,
wherein the control variable is a torque and is monitored in step a) by means of the controller, preferably by a controller of the frequency converter, and/or

wherein the control variable is a torque and is monitored in step a) at the drive shaft or at a coupling operatively connected to the drive shaft, preferably by means of strain gauges.

43. A method for filtering highly viscous fluids by means of a filtering device, in particular by means of a filtering device,

wherein the filtering device has a filtration unit for removing impurities from a highly viscous fluid, a discharge unit for discharging a free-flowing mass containing the removed impurities and that cooperates with the filtration unit, at least one drive means for driving the filtration unit, and/or the discharge unit, and

wherein the method comprises the steps of:

conveying the highly viscous fluid to be cleaned through the filtration unit and thus removing impurities from the highly viscous fluid;

discharging by means of the discharge unit a free-flowing mass containing the removed impurities;

driving the filtration unit and/or the discharge unit by means of the at least one drive means; and

controlling the filtering device by means of the controller according to a method according to claim 27.

44. A filtering device for filtering highly viscous fluids, comprising:
a filtration unit for removing impurities from a highly viscous fluid,
a discharge unit for discharging a free-flowing mass containing the removed impurities from the filtering device and that cooperates with the filtration unit,

at least one drive means for driving the filtration unit and/or the discharge unit, and

a controller for controlling the filtering device, in particular the drive means,

wherein the controller is configured to carry out a method according to claim 27 for controlling the filtering device.

45. The filtering device according to claim 44,

wherein the filtration unit and the discharge unit are jointly driven by the drive means, and

wherein the controller is configured to provide a correcting variable for the drive means.

46. The filtering device according to claim 45,

wherein the drive means is a first drive means which is configured to drive the filtration unit, and the filtering device has a second drive means which is configured to drive the discharge unit, and

wherein the controller is configured to provide a first correcting variable (n) for the first drive means and a second correcting variable (n) for the second drive means.

47. The filtering device according to any one of claim 44, further comprising:

a memory which is associated with the controller and is configured to store and to provide to the controller one, more or all of the following system variables:

- a start-up correcting variable,
- a maximum correcting variable,
- a minimum correcting variable,
- a holding interval,
- a measurement interval (Δt_M),
- a number of measurement points,
- a minimum threshold value,
- a minimum trigger value,
- a tolerance range,
- a critical deviation, and/or
- a change in the correcting variable.

48. The filtering device according to claim 44, further comprising:

a display device configured to display a current correcting variable in a predefined range of values, wherein the range of values is defined by the minimum correcting variable ($n_{\min}$) and/or the maximum correcting variable ($n_{\max}$), and/or is defined as a percentage of the maximum correcting variable.

49. The filtering device according to any one of claim 44,

wherein a filter element is designed as a sieve drum, and the filtering device also has a cleaning unit having a plurality of scraper members,

wherein the sieve drum is designed as a vertical sieve drum, and the cleaning unit is coupled to the drive means and is driven rotationally about a rotational axis (A), or

wherein the cleaning unit is designed as a vertical cleaning unit, and the sieve drum is coupled to the drive means and driven rotationally about a rotational axis (A).

50. The filtering device according to claim 44,

wherein the discharge unit has a dirt outlet and a discharge screw which is coupled to the drive means, in particular to a drive shaft, and which is designed to convey the free-flowing mass from the filtration unit towards the dirt outlet, or

wherein the discharge unit has a piston pump, in particular an axial piston pump, having at least one piston that is driven linearly by rotation of the drive shaft to perform a stroke action in such a manner that a containment volume is formed sequentially depending on the stroke action of the piston, in which the free-flowing mass is received, and is further reduced to discharge the free-flowing mass from a receiving chamber to a dirt outlet.

51. The filtering device according to claim 50, further comprising:

a coupling which is operatively connected to the drive shaft and which is fitted with at least one strain gauge for determining a torque of the drive shaft as a control variable.

52. The filtering device according to claim 51,

wherein the drive means comprises an electric motor having a frequency converter, the frequency converter being configured to control a speed of the electric motor, and

wherein the control variable is provided by the frequency converter, in particular by a control interface of the frequency converter.

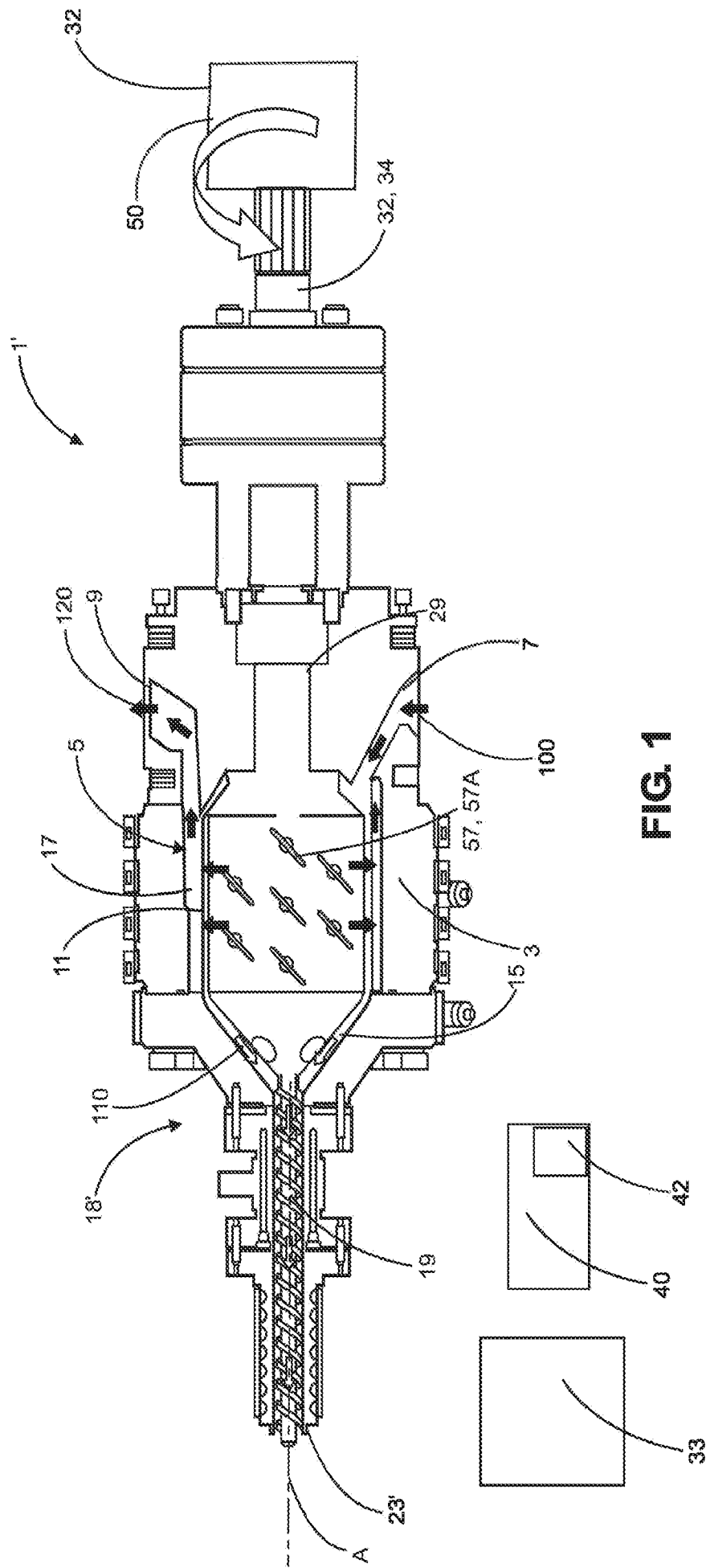
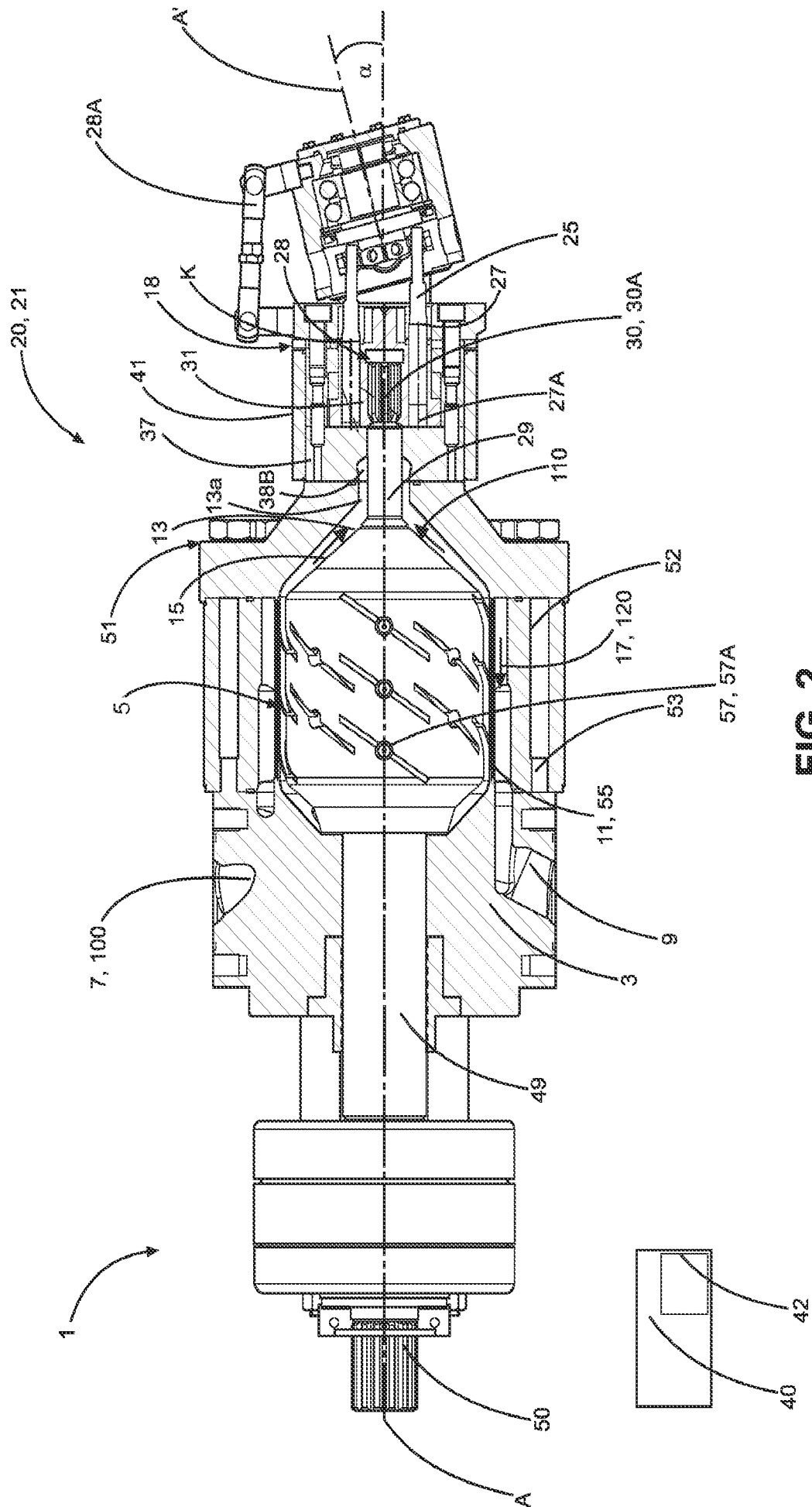


FIG. 1



2011

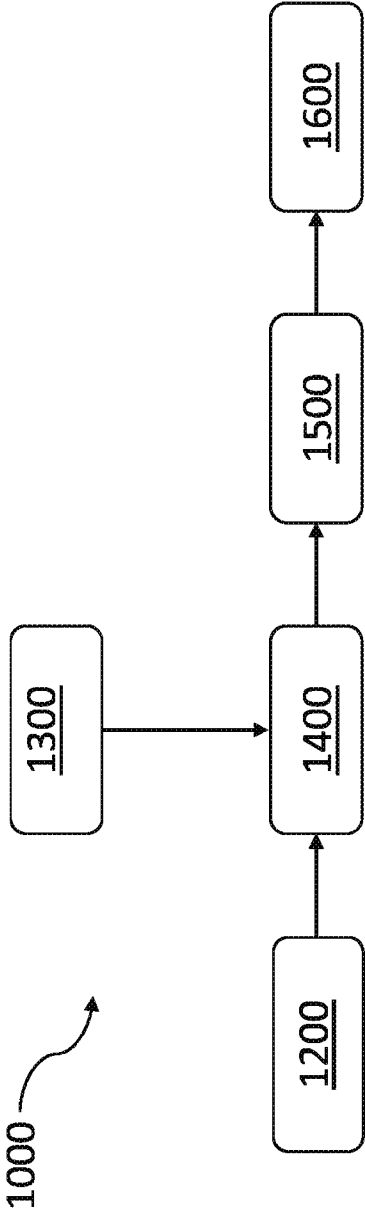


FIG. 3

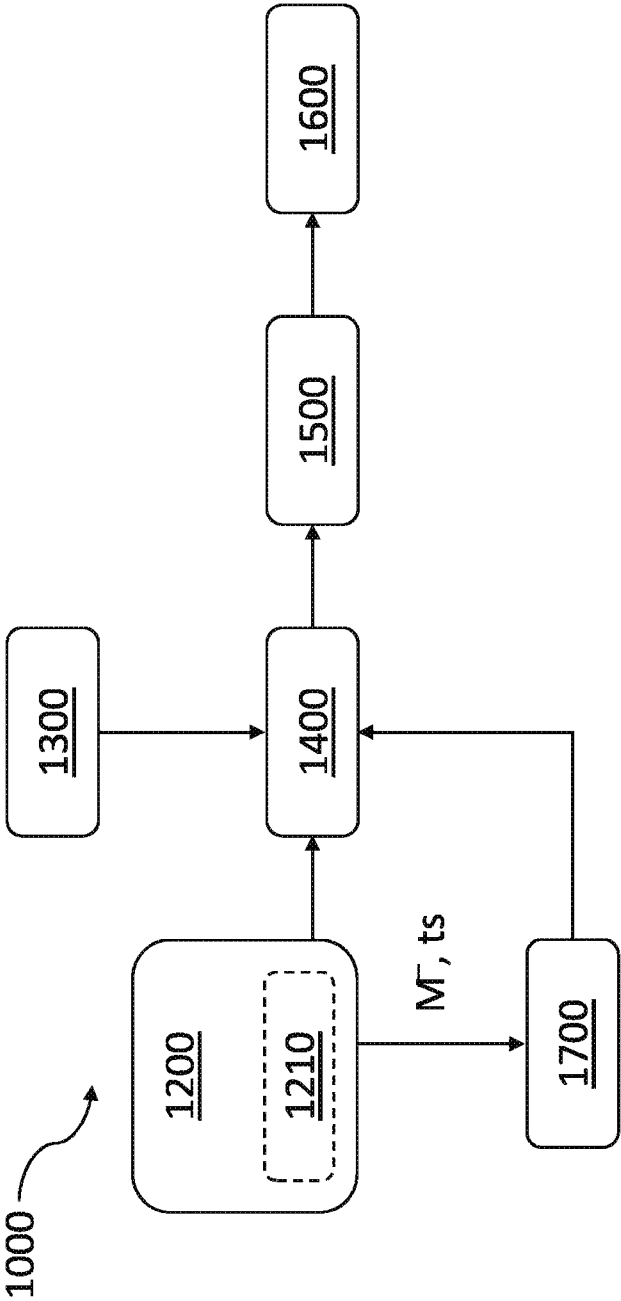


FIG. 4

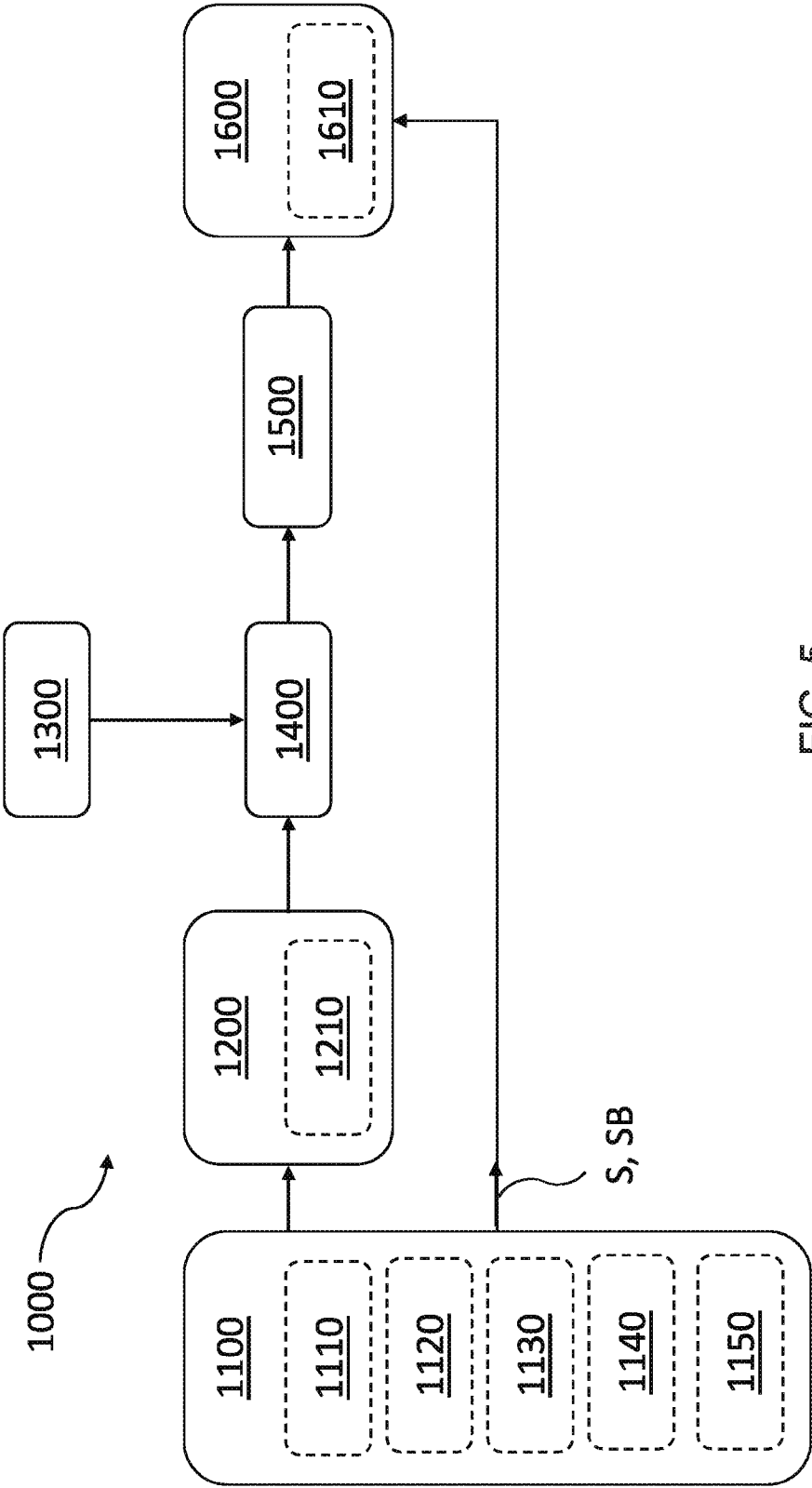


FIG. 5

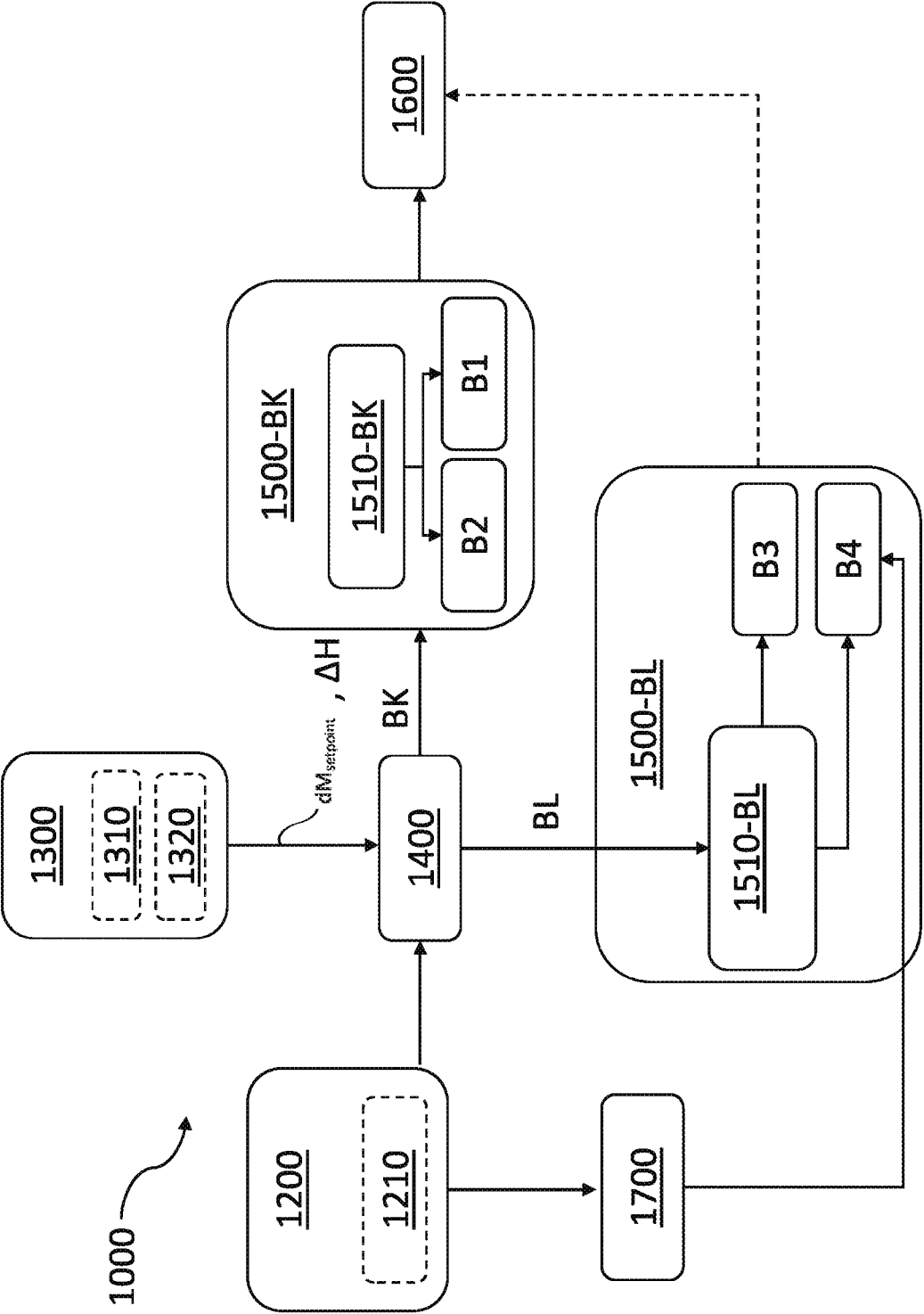


FIG. 6

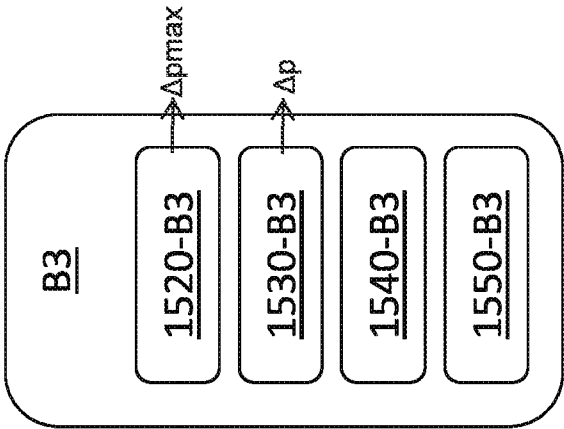


FIG. 7a

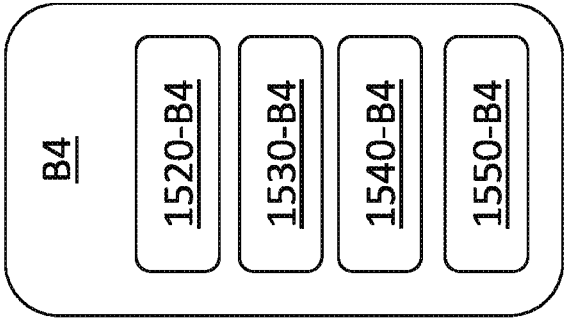


FIG. 7b

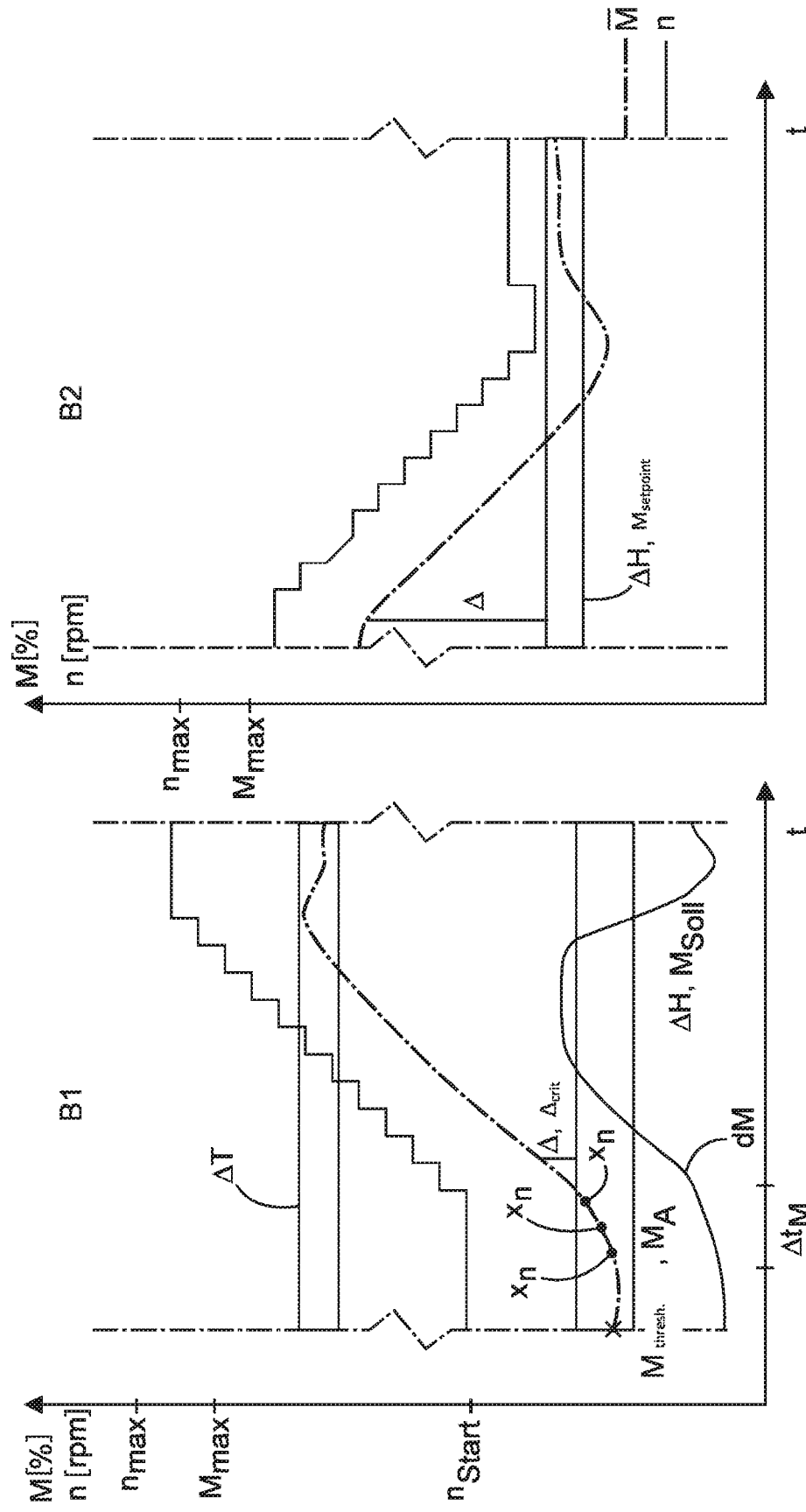
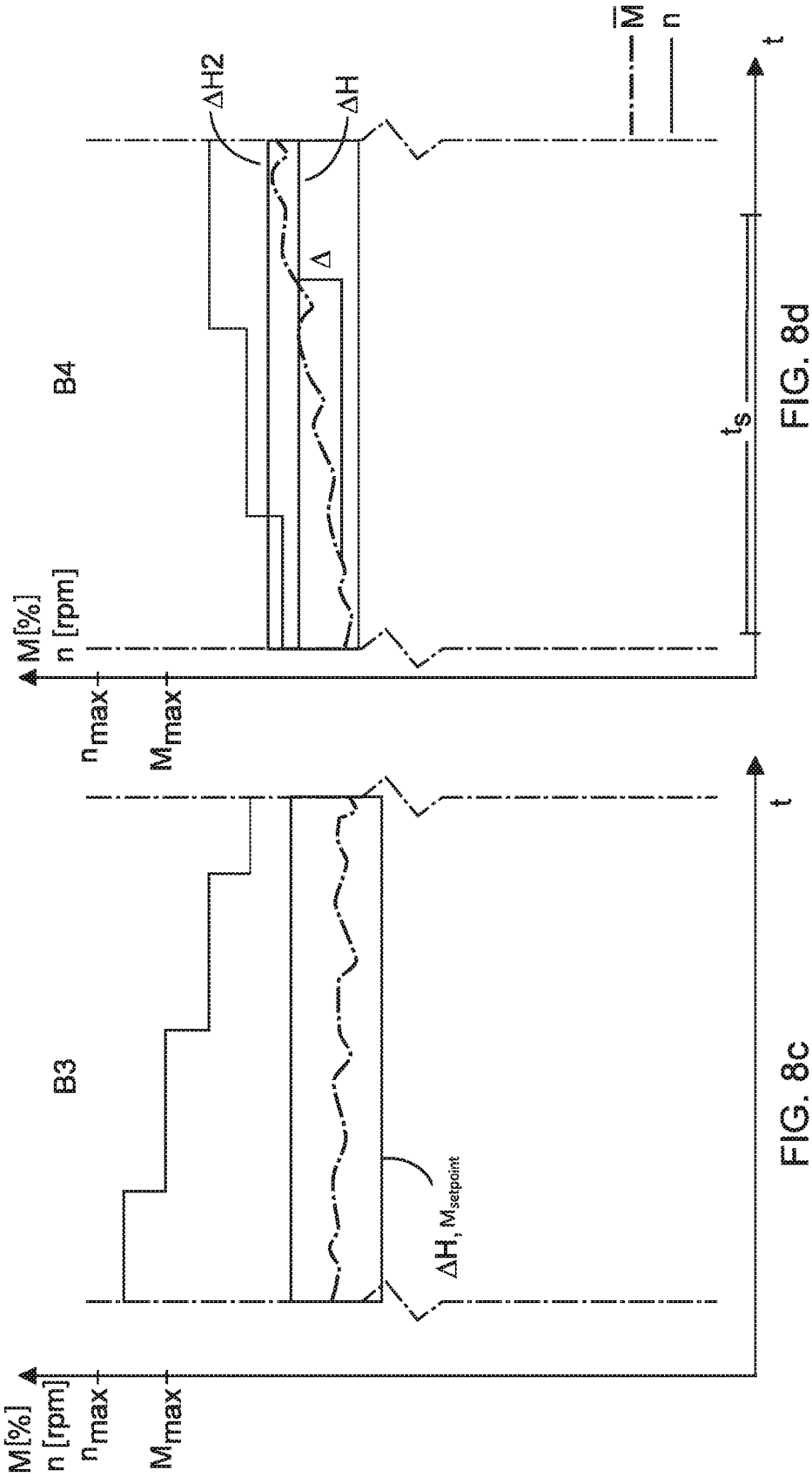


FIG. 8a

FIG. 8b



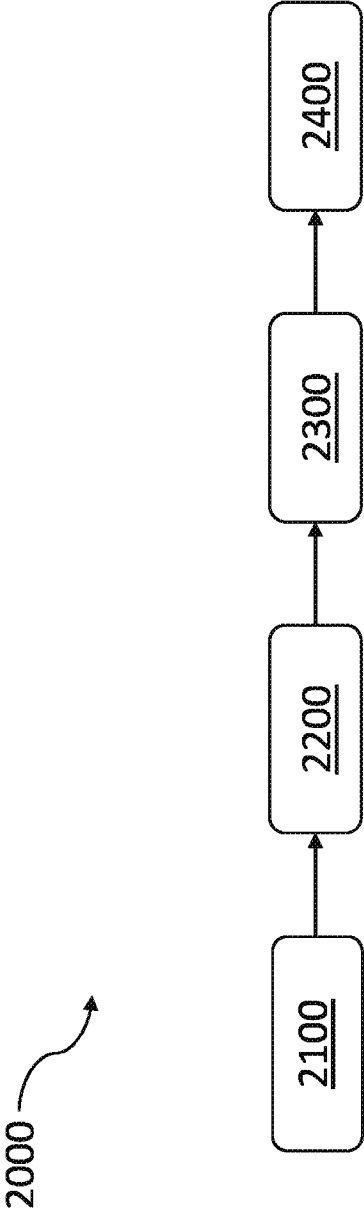


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2024/027382

A. CLASSIFICATION OF SUBJECT MATTER

INV. B29C48/694 B29C48/92

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 470 904 A (GAIL JOSEF [DE] ET AL) 11 September 1984 (1984-09-11) cited in the application	1-6, 16-52
Y	column 11, line 38 - column 13, line 38; figures 7-11	7-15
X	US 2005/161391 A1 (ETTLINGER RODERICH [DE]) 28 July 2005 (2005-07-28) paragraphs [0022] - [0027]; figures 1-6	1-6, 16-52
Y	US 2021/285803 A1 (KITAJIMA NOBUYUKI [JP] ET AL) 16 September 2021 (2021-09-16) paragraphs [0033], [0034], [0048] - [0051], [0086] - [0107]; figures 1-16	7-15



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

19 August 2024

Date of mailing of the international search report

10/09/2024

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Horubala, Tomasz

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2024/027382

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