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(54) **METHOD FOR CONTROLLING THE SPEED OF A COMPRESSOR/VACUUM PUMP**

(57) The present invention is directed to a method
for regulating the speed of a compressor/vacuum ele-
ment, said method comprising the steps of:

- starting the compressor/vacuum element (1);
- regulating the pressure within the compressor/vacuum element (1) by adjusting the volume of fluid flowing between a process channel (4) and the compressor/vacuum element (1) relative to the difference between the pressure value within said compressor/vacuum element (1) and a preset pressure value;

characterized in that the method further comprises the steps of:

- connecting the compressor/vacuum element (1) to a process channel (4) after the speed of the compressor/vacuum element (1) reaches a preset speed value; and
- adjusting the speed of the compressor/vacuum element (1) such that the power of the compressor/vacuum element (1) is maintained at a relatively constant value.

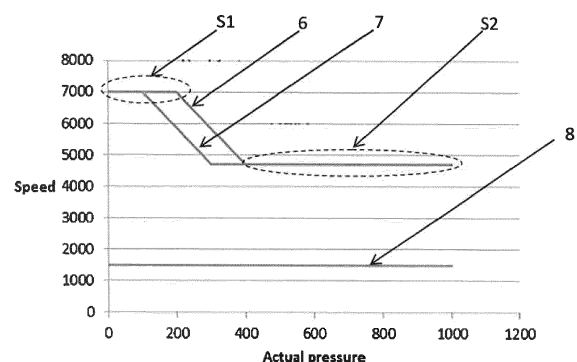


Figure 2.

Description

[0001] This invention relates to a method for regulating the speed of a compressor/vacuum pump, said compressor/vacuum pump being provided with a pressure regulating valve mounted on an influence channel, said influence channel being in direct fluid communication with the compressor/vacuum element, said valve regulating the pressure within the compressor/vacuum element by adjusting the volume of fluid flowing between a process channel and the vacuum element relative to the difference between the pressure value within said compressor/vacuum element and a set pressure value.

[0002] The life span of a motor driving a compressor/a vacuum pump is directly dependent on the number and the frequency of high load requests. Accordingly, when a compressor/vacuum pump is driven at maximum power, the risk of motor damages increases considerably. Because of such risk, known systems like the one described in US 2013/323,082 proposes a speed controller capable of adjusting the speed of the motor based on the pressure ratio of outlet to inlet pressure and an optimal speed of a centrifugal compressor determined based on a minimum allowable value of the volume of fluid passing through the compressor, until the compressor is likely to enter in surge conditions.

[0003] Accordingly, the speed of the compressor is determined based on the pressure ratio that lies along a peak efficiency operating line of the centrifugal compressor, and is increased when this parameter is less than a minimum allowable value or decreased when this parameter is greater than or equal to a minimum allowable value.

[0004] One of the drawbacks of the system introduced in US 2013/323,082 is the complexity. For determining the optimal speed line, the controller needs to take into account a significant number of parameters, such as the ratio of outlet to inlet pressure, the optimal speed of a centrifugal compressor determined based on a minimum allowable value of the volume of fluid passing through the compressor and a graph of the efficiency operating line. Furthermore, such a graph can vary depending on the temperature measured by a transducer. Such a complex determination requires high computational power which increases the system cost.

[0005] Another drawback of the proposed method consists in that, because the speed is compared with a minimum allowable value, in a real operation mode, this will generate frequent speed fluctuations and accordingly a premature wear of the motor.

[0006] Because the speed fluctuates due to external parameters, the noise generated by the compressor/vacuum system also fluctuates in intensity, generating an unwanted noise effect and an instable behavior.

[0007] Taken the above mentioned drawbacks and risks into account, it is an object of the present invention to provide a method and a system that reduces the occurrence of speed fluctuations within the compres-

sor/vacuum pump.

[0008] It is another object of the present invention to reduce the noise intensity fluctuation.

[0009] Yet another object of the present invention is to use the motor driving the compressor/vacuum pump at its maximum capacity and without experiencing malfunctions or jeopardizing the motor's life span.

[0010] The present invention further aims at reducing the frequency of maintenance interventions and increasing the efficiency of a compressor/vacuum pump without increasing the complexity of the design.

[0011] The present invention solves at least one of the above and/or other problems by providing a method for regulating the speed of a compressor/vacuum element, said method comprising the steps of:

- starting the compressor/vacuum element;
- regulating the pressure within the compressor/vacuum element by adjusting the volume of fluid flowing between a process channel and the compressor/vacuum element relative to the difference between the pressure value within said compressor/vacuum element and a preset pressure value

wherein the method further comprises the steps of:

- connecting the compressor/vacuum element to a process channel after the speed of the compressor/vacuum element reaches a preset speed value; and
- adjusting the speed of the compressor/vacuum element such that the power of the compressor/vacuum element is maintained at a relatively constant value.

[0012] Because the method according to the present invention comprises the step of connecting the compressor/vacuum element to a process channel after the speed of the compressor/vacuum element reaches a preset value, the compressor/vacuum element has enough time to reach a relatively lower pressure than the value measured when the system is started, increasing the responsiveness of the system when it is connected to the process channel.

[0013] In case the system comprises a vacuum element, another benefit of connecting the vacuum element to the process channel after the speed within the vacuum element reaches a preset value consists in that a purge cycle can be applied at the inlet of the vacuum element before it is connected to the process channel, allowing for a system clean-up.

[0014] Because the power of a vacuum pump is dependent on the torque and the speed of the vacuum element, and since the modulus of the torque is higher when the vacuum element is started or when the vacuum element is working at a relatively high pressure at the inlet channel, the time interval in which the pressure regulating valve keeps the vacuum element not connected to the process channel allows the vacuum element to

reach lower values for the modulus of the torque which will allow the system to reach higher speeds when connected to the process channel while keeping the value of the power relatively constant. If the vacuum element would be connected to the process channel immediately after it is started, the system would reach a high speed much later because of the high value of the modulus of the torque and accordingly would be less efficient.

[0015] Because of the pressure regulating valve, during this time interval, the system does not experience significant speed fluctuations that could have been caused by pressure variations. Accordingly, if the pressure at the inlet of the vacuum element is higher than the set value, the pressure regulating valve will maintain the pressure within the vacuum element relatively constant. Accordingly, the motor driving the vacuum pump is used at a relatively constant speed and at high efficiency, fact that increases its life span, and the life span of all rotating elements within the system.

[0016] Because the system does not experience significant speed fluctuations, noise intensity fluctuations are also minimized, allowing the compressor/vacuum pump to be used in a larger variety of applications.

[0017] Because the compressor/vacuum element is connected to the process channel after the speed of the compressor/vacuum element reaches a preset speed value, the yield of the compressor/vacuum pump is increased.

[0018] The present invention is further directed to a controller unit, being configured to regulate the speed of a compressor/vacuum element, the controller unit comprising:

- a data communication interface for receiving parameters relating to the current of a motor driving the compressor/vacuum element;
- means of comparing the data received from said motor with a predetermined current value saved within a database;
- a pressure regulating valve intended to be mounted on an influence channel, said influence channel being in direct fluid communication with the compressor/vacuum element, said valve regulating the pressure within the compressor/vacuum element by adjusting the volume of fluid flowing between a process channel and the compressor/vacuum element relative to the difference between the pressure value within said compressor/vacuum element and a preset pressure value

wherein the controller unit further comprises:

- means for connecting the compressor/vacuum element to a process channel after the speed of the compressor/vacuum element reaches a preset speed value
- a data communication channel for sending a control

signal to said motor for increasing or decreasing the rotational speed of the motor if the received current parameters are not between a predetermined maximum and/or a minimum current value.

[0019] By using such a controller unit, the complexity of the compressor/vacuum pump, the manufacturing and maintenance costs are kept to a minimum.

[0020] The present invention is further directed to a compressor/vacuum pump being provided with a pressure regulating valve and a controller unit according to the present invention.

[0021] The present invention is further directed to a use of a controller unit according to the present invention for maintaining the speed of a compressor/vacuum element between a first maximum speed variance graph and a second maximum speed variance graph.

[0022] With the intention of better showing the characteristics of the invention, a preferred method and configuration of a system according to the present invention is described hereinafter by way of an example without any limiting nature, with reference to the accompanying drawings, wherein:

figure 1 discloses a compressor or vacuum pump according to an embodiment of the present invention;

figure 2 discloses a first maximum speed variance graph and a second maximum speed variance graph according to an embodiment of the present invention;

figure 3 discloses an algorithm according to an embodiment of the present invention for controlling the first maximum speed variance graph and the second maximum speed variance graph according to the measured current;

figure 4 discloses a pressure regulating valve according to an embodiment of the present invention; and

figure 5 discloses a pressure regulating valve according to another embodiment of the present invention.

[0023] The present invention is directed to a method for regulating the speed of a compressor/vacuum element 1, said method comprising the steps of starting the compressor/vacuum element 1 (Figure 1) and regulating the pressure within the compressor/vacuum element 1 by adjusting the volume of fluid flowing between a process channel 4 and the compressor/vacuum element 1 relative to the difference between the pressure value within said compressor/vacuum element 1 and a preset pressure value.

[0024] In the context of the present invention it is considered that once the compressor/vacuum element 1 is started, the pressure value at the level of the compressor/vacuum element 1 determines the motor driving said compressor/vacuum element 1 to work at high power.

Said power being dependent on the torque and the rotational speed of at least one rotor within the compressor/vacuum element 1.

[0025] In the context of the present invention, the torque should be understood as a measured ability of a rotating element, as of a gear, a shaft or a rotor to overcome turning resistance.

[0026] Once the compressor/vacuum element 1 is started, the modulus of the torque at the level of the at least one rotor within the compressor/vacuum element 1 is considerably high due to a high pressure at the level of the influence channel 5, and accordingly even if the motor 2 functions at high power, the rotational speed of the rotor(s) is low. As the compressor/vacuum element 1 continues to function, the modulus of the torque will gradually decrease, and accordingly the speed of the rotor(s) within the compressor/vacuum element 1 can be gradually increased by the system.

[0027] In other words, even if the motor 2 is working at a high power, the system cannot allow the rotor(s) to reach a high speed immediately after the compressor/vacuum element 1 is started.

[0028] Because the method according to the present invention adjusts the speed of the compressor/vacuum element 1 such that the power of said compressor/vacuum element 1 is maintained at a relatively constant value, once the torque lowers, the speed is allowed to increase. Accordingly, the motor 2 does not experience significant variations while the pressure regulating valve 3 is adjusting the volume of fluid flowing between a process channel 4 and the compressor/vacuum element 1 and the system reaches a high yield in a minimum time interval, increasing the efficiency and decreasing the waiting time interval.

[0029] Because the power of the system is maintained at a relatively constant value, the motor 2 used by the compressor/vacuum element 1 is allowed to work within a high range of working parameters for a significantly long amount of time. Because of this, the motor 2 is neither overloaded nor under-loaded, increasing the efficiency of the compressor or vacuum pump and, at the same time, protecting the motor 2.

[0030] Preferably, the method according to the present invention allows the motor 2 driving the compressor/vacuum element 1 to work within the high range of working parameters throughout the entire functioning interval when a request for compressed air or vacuum is encountered.

[0031] In the context of the present invention it is to be understood that a compressor/vacuum element 1 is part of a compressor or vacuum pump which can be selected from a group comprising: a single screw compressor, a double screw compressor, a scroll compressor, a turbo compressor, a single toothed vacuum pump, a double toothed vacuum pump, a single screw vacuum pump, a double screw vacuum pump, a scroll vacuum pump, a turbo vacuum pump, a rotary vane vacuum pump, etc. Each of the above identified types of compressor/vacuum

elements 1 can be oil injected or oil free.

[0032] In the context of the present invention it is to be understood that a compressor/vacuum element 1 comprises at least a rotor enclosed within a chamber. For ease of explanation, the rotational speed of the at least one rotor of the compressor/vacuum element 1 is hereinafter referred to as the speed of the compressor/vacuum element 1.

[0033] The method further comprises the step of providing a pressure regulating valve 3 on an influence channel (not shown), said influence channel being in direct fluid communication with the compressor/vacuum element 1, said valve 3 regulating the pressure within the compressor/vacuum element 1 by adjusting the volume of fluid flowing between a process channel 4 and the compressor/vacuum element 1 relative to the difference between the pressure value within said compressor/vacuum element 1 and a preset pressure value.

[0034] Because the method comprises the step of providing a pressure regulating valve 3 on the influence channel, and because the compressor/vacuum element 1 is connected to the process channel 4 after the speed of the compressor/vacuum element 1 reaches a preset speed value, the motor 3 has a sufficient amount of time to reach a state in which the modulus of the torque is low enough to allow the motor 3 to considerably increase the rotational speed of the rotor(s).

[0035] In an embodiment according to the present invention, the pressure regulating valve 3 is preferably kept in a closed state or in an approximately closed state during the time interval in which the compressor/vacuum element 1 reaches said preset speed.

[0036] In an embodiment according to the present invention, if the system is a compressor, the compressor element can be connected to the process channel 4 immediately after the compressor element is started.

[0037] Preferably, the pressure regulating valve 3 (Figure 4 or Figure 5) is comprising a housing V5 delimiting a first chamber V6 and a second chamber V7 separated by a wall V8. The first chamber V6 comprises a movable element V9 that defines a first cavity V6a and a second cavity V6b fluidly sealed from each other. The first cavity V6a comprising an inlet channel V10 connected to a first supply of a fluid, and means for exerting a force on the movable element V9.

[0038] Preferably, said wall V8 acts as a separation between the second chamber V7 and the second cavity V6b of the first chamber V6.

[0039] The housing V5 can for example comprise a lid V5a.

In this case but not necessarily, the inlet channel V10 is provided centrally on the lid V5a opposite from the second cavity V6b.

[0040] The second chamber V7 is in direct communication with a process channel 4 of a supply of a fluid and further comprises therein a valve body V11 having a distal end V11a extending into the first cavity V6a of the first chamber V6 and a proximal end V11b, said valve body

V11 being movable between an initial closed state in which the proximal end V11b is pushed against a sealing flange V12 and a second, opened state, in which a fluid flows between the process channel 4 and the influence channel 5 of the compressor/vacuum element 1.

[0041] In the context of the present invention it is to be understood that the housing V5 can be made by one integral part or several separate parts.

[0042] The valve body V11 is slidably mounted in the wall V8 in such a way as to prevent a fluid flow between the second chamber V7 and the second cavity V6b of the first chamber V6.

[0043] Preferably, the sealing flange V11 is forming an opening towards the influence channel 5 of the compressor/vacuum element 1.

[0044] In a preferred embodiment according to the present invention the valve body V11 is mounted within a guide V13, in this case in the shape of a pipe-shaped element, comprising a seal V14 and a bushing V15 mounted at the level of the guide V13 to eliminate the risk of encountering any residual fluid flow between the second cavity V6b of the first chamber V6 and the second chamber V7.

[0045] Preferably the valve body V11 comprises a fluid channel V16 extending through said valve body V11 allowing a fluid flow between the first cavity V6a and the influence channel 5 of the compressor/vacuum element 1. Accordingly, the pressure within the first cavity V6a will have the same value as the pressure value of the fluid at the influence channel 5 of the compressor/vacuum element 1.

[0046] The movable element V9 can for example be in the shape of a membrane, or a piston, or a metal plate.

[0047] Preferably, said means for exerting a force on the movable element V9 can be in the shape of: a spring, a piston or a metal plate such as a steel plate for which exerting a force on the movable element V9 is intrinsic in the material properties. The force generated on the movable element V9 can either be compressive or tensile.

[0048] Preferably, the means for exerting a force on the movable element V9 comprise a spring V17 positioned in the first cavity V6a and pushing on said movable element V9.

[0049] The spring V17 can be, for example, positioned centrally within said cavity V6a of the first chamber V6 and pushing on a centrally positioned surface on the movable element V9.

[0050] Preferably, the housing V5 comprises a collar V18 around the inlet channel V10 for positioning said spring V17 and keeping it in a stable central position. The inlet channel V10 can be positioned concentrically with respect to said collar V18.

[0051] In another embodiment according to the present invention, the inlet channel V10 can be positioned on the lateral sides of the lid V5a.

[0052] Preferably, the spring V17 is generating in an initial closed state a force F_1 of less than 3000N (Newton),

more preferably the spring V17 is generating a force F_1 of less than 2000N, even more preferably, the spring V17 is generating a force F_1 of 1000N or less.

[0053] In a preferred embodiment, the spring V17 is generating in an initial closed state a force F_1 in the range from 500 - 2000N.

[0054] Preferably, the proximal end V11b pushing against the sealing flange V12 is, in this example, in the shape of a frustum of a cone with rounded edges having the base with the biggest diameter at the end facing the second chamber V7 and the base with the smallest diameter at the end facing influence channel 5 of the compressor/vacuum element 1.

[0055] Preferably, the proximal end V11b has a hollow cavity V19 at the end facing the influence channel 5 of the compressor/vacuum element 1.

[0056] The pressure regulating valve 3 preferably comprises two guiding elements V20 and V21 for guiding the movable element V9: the first guiding element V20 being positioned in the second cavity V6b of the first chamber V6 between the movable element V9 and the wall V8 separating the first chamber V6 and the second chamber V7, and the second guiding element V21 being positioned in the first cavity V6a of the first chamber V6, between the movable element V9 and the spring V17.

[0057] The movable element V9 can be in the shape of a piston, or a metal plate. Preferably, the movable element V9 is a membrane fixed in the housing V5 of the first chamber V6.

[0058] In another embodiment according to the present invention the first guiding element V20 is in the shape of a cylindrical block with a hollow carving created on the side facing the wall V8 for receiving the guide V13 therein.

[0059] In another embodiment according to the present invention the first guiding element V20 is in the shape of a disk having a hole therein for receiving the valve body V11.

[0060] The second guiding element V21 can be in the shape of a disk against which, on one side the spring V17 is resting, and has a hole therein for receiving the valve body V11.

[0061] Preferably, the guiding element V21 comprises a circumferential rim extending towards the lid V5a.

[0062] Preferably, the second cavity V6b of the first chamber V6 further comprises an inlet channel V22 fluidly connecting said second cavity V6b to a supply of a first fluid at pressure P_1 .

[0063] For ease of design, the first fluid is preferably air and P_1 is preferably the atmospheric pressure.

[0064] For controlling the volume of fluid flowing through the inlet channel V10 of the first cavity V6a of the first chamber V6 and through the valve body V11 towards the influence channel 5 of the compressor/vacuum element 1, the inlet channel V10 of the first cavity V6a of the first chamber V6 further comprises means for sealing said first cavity V6a from the fluid flow at pressure P_1 .

[0065] Preferably but not limiting to, said means for

sealing said first cavity 6a from the fluid flow is a valve 10.

[0066] In an embodiment according to the present invention, if the system comprises a vacuum pump, said vacuum pump is preferably subjected to a purge cycle before being connected to the process channel 4 for cleaning the system of impurities.

[0067] If the system comprises a vacuum pump, the influence channel is integrally comprised or in direct fluid communication with the inlet channel of the vacuum pump.

[0068] In an embodiment according to the present invention, when the vacuum element is subjected to a purge cycle, the pressure regulating valve 3 is maintained in a closed state. Once the vacuum element is connected to an external process, the pressure regulating valve 3 will control the volume of fluid flowing between the process channel 4 and the vacuum element as will be further explained.

[0069] If the pressure at the inlet channel of the vacuum element, P_{element} , is lower than a minimum set value, the valve body V11 slidably moves against the force generated by the spring V17 in the direction of the first chamber V6, lifting the proximal end V11b of the valve body V11 from the sealing flange V12) and allowing a fluid flow between the process channel 4 and the inlet channel of the vacuum element.

[0070] When the pressure value at the inlet channel of the vacuum element reaches a value sufficiently high such that the pressure difference between the first cavity V6a and the second cavity V6b of the first chamber V6 is sufficiently low to allow the proximal end V11b of the valve body V11 to move towards the sealing flange V12 and reduce the flow of fluid. If the pressure within the inlet channel of the vacuum element is still too high, the proximal end V11b of the valve body V11 is moved until it is pushed against said sealing flange V12, completely stopping the fluid flow between the process channel 4 and the inlet channel of the vacuum element.

[0071] In a preferred embodiment according to the present invention, the pressure value at which the proximal end V11b of the valve body V11 is lifted from the sealing flange V12 and/or is pushed against the sealing flange V12 is adjusted depending on the application at which the vacuum pump is connected to.

[0072] Preferably, when P_{element} is higher than a minimum set value, the proximal end V11b is pressing against the sealing flange V12 and a flow of fluid flows through the fluid channel V16. When P_{element} is equal to or lower than the minimum set value, the valve 10 closes and no fluid flows through the fluid channel V16, the pressure regulating valve 3 entering in a modulating state. The pressure P_{element} and the pressure value within the process channel 4 is influenced in such a state by the variable speed drive unit or inverter, part of the driving means of the vacuum pump.

[0073] Preferably, said driving means can be a combustion engine or an electrical motor, a turbine such as a water turbine or a steam turbine, or the like.

[0074] The driving means can be directly driven or can be driven by an intermediate transmission system like a coupling or a gear box.

[0075] Because the vacuum pump according to the present invention uses a pressure regulating valve 3 as described above, a permanent flow of fluid throughout the valve body V8 can be maintained during the purge cycles, increasing the volume of fluid flowing throughout the vacuum element and increasing the reliability of such purge cycles. Accordingly the time intervals allocated for performing the purge cycles can be reduced.

[0076] Preferably, but not necessarily, the pressure regulating valve 3 is of a type as described in patent application BE 2015/5072, which is herein incorporated by reference in its entirety.

[0077] In the context of the present invention it is to be understood that other types of valves, having a different structure can be used as well.

[0078] In a preferred embodiment according to the present invention, because during the purge cycle the speed of motor driving the vacuum pump is relatively high, the system will preferably reduce said speed to a set speed before connecting the vacuum element to the external process. Said set speed can be any value of the speed selected in the interval 500 - 4600 rpm (revolutions per minute). For example, and not limiting to, the set speed can be selected as being approximately 3500 rpm.

[0079] Because of this step, even if the pressure value at the level of the external process is relatively high, the pressure difference between the pressure value at the level of the external process and the pressure value at the level of the vacuum element would not cause the motor to be overloaded or to trip.

[0080] Preferably, said valve 10 is connected to a supply of a purge gas through a nozzle (not shown).

[0081] In a preferred embodiment according to the present invention the nozzle of valve 10 has a diameter much bigger than the nozzle at the level of the distal end V11a of the pressure regulating valve 3. Because of this, when the valve 10 is opened, a fluid flow is kept from the valve 10, through the pressure regulating valve 3 and into the influence channel 5 of the vacuum element 1.

[0082] In a preferred embodiment according to the present invention, when the vacuum element 1 is subjected to a purge cycle, the system will function at a relatively high speed for a predetermined time interval in order to achieve a preset temperature.

[0083] Said predetermined time interval can be selected for example between 1 minute and 3 hours, depending on the requirements of each process.

[0084] Said preset temperature can be selected between 60 - 105°C, like for example, the preset temperature can be 80°C, or said temperature can be 103°C.

[0085] Preferably, during the purge cycle, the system maintains the pressure within the vacuum element 1 at a desired value. Such a value can be any value selected between 5 - 1000 mbar, depending on the requirements on the process channel 4.

[0086] In a preferred embodiment according to the present invention, when the vacuum element 1 is connected to the external process, the valve 10 is brought in a closed state, such that the vacuum element 1 influences the pressure within the process channel 4 with a maximum yield.

[0087] In a preferred embodiment according to the present invention, when the pressure in the influence channel 5 is rising, the speed of the compressor/vacuum element 1 is regulated according to a pre-determined first maximum speed variance graph 6 (Figure 2).

[0088] In another preferred embodiment according to the present invention, when the pressure in the influence channel 5 is decreasing, the speed of the compressor/vacuum element 1 is regulated according to a pre-determined second maximum speed variance graph 7.

[0089] Preferably, the method further comprises a step in which a minimum allowed speed 8 for the compressor/vacuum element 1 is determined, as the limit until which the compressor/vacuum element 1 is maintained within nominal working parameters. Preferably, said minimum allowed speed 8 is different than the pre-determined first maximum speed variance graph 6 and/or the second maximum speed variance graph 7.

[0090] Because the system according to the present invention does not use a linear speed limit, but a first maximum speed variance graph 6 and/or a second maximum speed variance graph 7, the frequency of speed variations of the motor 2 driving the compressor/vacuum element 1 is kept to a minimum. Accordingly, when the compressor/vacuum element 1 experiences pressure variations, and because the power is kept at a relatively constant value, the rotational speed of the rotor(s) will also suffer variations. If the system would apply a single maximum speed variance graph, the motor 2 would experience oscillations each time the rotational speed of the rotor(s) would reach a higher or lower value than the one of the limit. This effect would increase the chances for the motor 2 to experience malfunctions and will also create fluctuations of sound intensity, limiting the applications in which the system could be used.

[0091] By adjusting the speed after a first maximum speed variance graph 6 and/or a second maximum speed variance graph 7, the system will not adjust the speed of the rotor(s) immediately when a change in pressure is sensed, but when the value of the speed is equal with or lower than and/or equal with the values on the border line of the second maximum speed variance graph 7 and/or the first maximum speed variance graph 6.

[0092] In a preferred embodiment according to the present invention, when the system experiences a decrease in pressure, the speed is adjusted after the second maximum variance graph 7 and/or when the system experiences an increase in pressure, the speed is adjusted after the first speed variance graph 6.

[0093] For optimizing the functioning of the system and reducing the variations in speed, the first maximum speed variance graph 6 and the second maximum speed

variance graph 7 determine a hysteresis type of behavior for the speed of the compressor/vacuum element 1. Because of this, the method according to the present invention is maintaining the motor 2 in a high range of functional parameters, keeping the yield of the system high.

[0094] In a preferred embodiment according to the present invention, the method further comprises the steps of: keeping the speed of the compressor/vacuum element 1 relatively constant until the preset pressure value of the pressure regulating valve 3 is reached; and after said pressure value is reached: increasing the speed of the compressor/vacuum element 1 in accordance with the second maximum speed variance graph 7; and/or decreasing the speed of the compressor/vacuum element 1 in accordance with the first maximum speed variance graph 6.

[0095] Because the system uses the pressure regulating valve 3 and because the fluid channel V16 allows a flow of fluid through the valve body until a preset speed of the compressor/vacuum element is reached, the pressure value at the level of the compressor/vacuum element 1 is maintained at a relatively constant value until optimal working parameters are reached. Because the pressure at the level of the compressor/vacuum element 1 is kept constant, the power of the motor 2 is also kept at a relatively constant value.

[0096] After the set speed is reached, the fluid channel V10 is preferably disconnected from the supply of fluid, causing the valve 3 to be brought into an open state and the pressure within the process channel 4 to be directly influenced by said compressor/vacuum element 1 at a maximum yield.

[0097] In a preferred embodiment according to the present invention, if the system comprises a vacuum element 1, the pressure within the vacuum element 1 is maintained at a relatively a constant value, until a preset pressure value is reached at the level of the influence channel 5. Preferably, the preset pressure value is less than 600 mbar, more preferably less than 500 mbar and most preferably is approximately 400 mbar.

[0098] In the context of the present invention it is to be understood that the preset pressure value can be selected depending on either the pressure value at which the vacuum element 1 is starting, or the requirements on the process channel 4, or the pressure difference between the pressure value at which the vacuum element 1 is starting and the desired pressure at the level of the process channel 4.

[0099] When the pressure value at which the vacuum element 1 is starting is atmospheric pressure, and the preset pressure value is selected as being approximately 400 mbar, the system encounters a pressure difference of approximately 600 mbar, which is sufficient for maintaining oil injection within an oil injected vacuum pump.

[0100] Preferably, when the vacuum element 1 is started, the motor will drive the rotor(s) at a predetermined starting speed and will gradually increase the speed until the set speed is reached and the vacuum element 1 is

then connected to the process channel 4, as previously explained.

[0101] Preferably, and not limiting to, said predetermined starting speed is not higher than the maximum speed of the motor reachable at the preset pressure value. Said predetermined starting speed can be selected as any value comprised between 600 and 4600 rpm, depending on the compressor/vacuum element 1 used.

[0102] In case the system comprises a vacuum element 1, said speed can be for example and not limiting to, approximately 3500 rpm.

[0103] For a more efficient and easier control of the speed of the compressor/vacuum element, the second maximum speed variance graph 7 does not reach a minimum preset speed value 8 of the compressor/vacuum element 1. Accordingly, the compressor or vacuum pump can be maintained within optimal working parameters.

[0104] In another embodiment according to the present invention, for protecting the motor 2 even more, the method according to the present invention applies the step of measuring the current passing through the motor windings; and comparing said measured current with a maximum allowed current. In one embodiment according to the present invention, if the measured current is lower than the maximum allowed current then the speed of the motor is increased according to the first maximum speed variance graph 6 or the second maximum speed variance graph 7.

[0105] Preferably, if the measured current is higher than the maximum allowed current then the speed of the motor is decreased according to the first maximum speed variance graph 6 or the second maximum speed variance graph 7. By applying such a step, it is assured that the inverter, part of the motor 2, is not experiencing any trips. Such an effect is undesired because it can cause the system to reset which would mean a delay for reaching the desired pressure value on the process channel 4 and accordingly a reduced efficiency of the compressor or vacuum pump. Another effect of performing such a step consists in that the motor 2 of the compressor or vacuum pump is kept within optimal parameters, without the risk to be overloaded. Accordingly, the yield of the system can be maintained within the high range throughout the complete functioning cycle without endangering the life span of the motor 2.

[0106] In a preferred embodiment according to the present invention, for a more efficient control of the speed, if the current passing through the motor windings is higher than the maximum allowed current, the first maximum speed variance graph 6 or the second maximum speed variance graph 7 is translated to lower values (Figure 3) and/or the minimum preset speed value 8 of the compressor/vacuum element 1 is translated to higher values. Furthermore, if the current passing through the motor windings is lower than the maximum allowed current, the first maximum speed variance graph 6 or the second maximum speed variance graph 7 is translated to higher values and/or the minimum preset speed value 8 of the

compressor/vacuum element 1 is translated to lower values.

[0107] By applying such a step the method according to the present invention does not influence the speed of the compressor/vacuum element 1 directly, but the first maximum speed variance graph 6 and/or the second maximum speed variance graph 7 and/or the minimum present allowed speed 8 value which create the speed limits between which the compressor/vacuum element 1 is allowed to function.

[0108] Accordingly the speed and sound fluctuations are kept to a minimum.

[0109] Preferably, the compressor or vacuum pump translates the first maximum speed variance graph 6 and/or the second maximum speed variance graph 7 and/or the minimum preset speed value 8 allowed when the current measured through the motor windings reaches a value higher than a maximum allowed current plus a tolerance selected between 0.1 - 2 A (Ampere).

[0110] In a preferred embodiment according to the present invention the controller unit is measuring the pressure on the influence channel at a sampling rate selected between 100 - 400 msec (milliseconds), more preferably the controller unit is measuring the pressure on the influence channel 5 at a sampling rate of 200 msec.

[0111] In a preferred embodiment the controller unit comprises a pressure controller, a speed controller and a limiting function.

[0112] Preferably, the pressure controller compares the measured pressure value within the process channel 4 with the requested pressure value and calculates the required speed of the element to reach the requested pressure value.

[0113] In the context of the present invention the requested pressure value should be understood as the pressure value needed at the level of the external process and selected by the user of the compressor/vacuum element 1.

[0114] Preferably, the limiting function determines two speed values for each pressure value measured: one maximum speed value corresponding to the value found on the borderline of the first maximum speed variance graph 6 or the second maximum speed variance graph 7 if a virtual line parallel to the speed axis is drawn through that measured pressure value, and a second minimum value found on the minimum preset speed value 8 graph, determined at the intersection between said virtual line and the minimum preset speed value 8 graph.

[0115] The limiting function further compares the requested speed with the two determined maximum and minimum speed values. If said requested speed is higher than the maximum speed value, then a set speed is preferably adjusted to said maximum speed value.

[0116] If said requested speed is lower than the minimum value, then the set speed is preferably adjusted to said minimum value.

[0117] If said requested speed is not higher than said maximum speed value or lower than the minimum value,

the limiting function preferably does not influence the set speed which will be equal to the requested speed.

[0118] Preferably the speed controller compares the set speed with the measured speed and adjusts the speed of the motor to match the set speed.

[0119] Furthermore, the controller unit preferably measures the current passing through the motor windings and compares said measured value with a predetermined maximum value. If the value of the measured current is higher than the predetermined maximum value, the controller unit preferably modifies the maximum speed value and/or the minimum speed value.

[0120] In a preferred embodiment according to the present invention, if the measured current is higher than the predetermined maximum value, the controller unit preferably translates the maximum speed value to lower values and/or the minimum speed value to higher values.

[0121] In the context of the present invention a translation of a value should be understood as a lower or higher value found on a virtually drawn line on a graph, said virtually drawn line being parallel with one of the axis, in this case with the speed axis, and being drawn as striking through the measured value.

[0122] In the context of the present invention it is to be understood that the controller unit is an electronic module capable of modifying a state of at least one component of the compressor/vacuum element 1.

[0123] In the context of the present invention it is to be understood that when it is specified that the controller unit influences the state of a component in a particular way such as for example and not limiting to: increases or decreases the speed of at motor of the compressor/vacuum element 1, or connects the compressor/vacuum element 1 to the process channel 4, the controller unit then generates a signal, for example an electrical signal, that changes the state of the at least one component.

[0124] In another embodiment according to the present invention the controller unit further compares said measured current value with a predetermined minimum value. If said measured value is lower than the predetermined minimum value, the controller unit translates the maximum speed value to higher values and/or the minimum speed value to lower values.

[0125] In a preferred embodiment according to the present invention, if the measured current is higher than the predetermined maximum value or lower than a predetermined minimum value, the controller unit modifies the maximum speed value and/or the minimum speed value of the compressor/vacuum element 1 even if the measured speed is not higher than said maximum speed value or lower than the minimum value. Because of this a compressor/vacuum element 1 using a controller unit according to the present invention can function at high values of the modulus of the torque at both high and low speeds.

[0126] Preferably, the controller unit considers a tolerance between 0.1 - 2 A (Ampere) before it modifies the

maximum speed value and/or the minimum speed value.

[0127] Because the controller unit performs such a comparison, the speed of the compressor/vacuum element 1 is not directly and immediately modified as is the case of existing systems, but the maximum speed value and/or the minimum speed value are being modified, which results in less speed fluctuations for the compressor/vacuum element 1 and accordingly less noise fluctuations.

[0128] Preferably, the speed limitation S1 (Figure 2) is determined by the mechanical limitation of the compressor/vacuum element 1, such as the limitation imposed by any of the following elements: motor 2, inverter, switching frequency of the inverter, bearings, materials used for rotor(s) or casing, noise limit, or the like.

[0129] If the system comprises a vacuum element 1, the speed limitation S2 is determined by the pressure regulating valve 3.

[0130] In the context of the present invention it is to be understood that the first maximum speed variance graph 6, the second maximum speed variance graph 7, the speed limitation S1 and/or the speed limitation S2 can be selected depending on the compressor/vacuum element 1 used and/or the requirements on the influence channel 5.

[0131] The present invention is further directed to a controller unit, being configured to regulate the speed of a compressor/vacuum element 1.

[0132] In the context of the present invention it is to be understood that said controller unit can be an integral part of the compressor or vacuum pump or can be an external module communicating with said compressor or vacuum pump.

[0133] The controller unit comprises a data communication interface for receiving parameters relating to the current of a motor driving the compressor/vacuum element 1. Preferably, the controller unit further comprises means of comparing the data received from said motor 2 with a predetermined current value saved within a database.

[0134] Said means of comparing the data received from said motor 2 with a predetermined current value can be for example a processor mounted at the level of the controller unit or at an external location.

[0135] Preferably, the compressor or vacuum pump comprises a pressure regulating valve 3 (Figure 4 or Figure 5) intended to be mounted on an influence channel 5, said influence channel 5 being in direct fluid communication with the compressor/vacuum element 1.

[0136] If the system comprises a vacuum element 1, said valve 3 is preferably regulating the pressure within the vacuum element 1 by adjusting the volume of fluid flowing between a process channel 4 and the vacuum element 1 relative to the difference between the pressure value within said vacuum element 1 and a preset pressure value.

[0137] Preferably, the preset pressure value can be selected depending on the requirements for the pressure

value at the level of the process channel 4. For example, such a value can be any selected value comprised within the interval, and not limiting to: 200-800 mbar.

[0138] In a preferred embodiment according to the present invention, if the system comprises a vacuum element, the preset pressure value is approximately 400 mbar.

[0139] Preferably, the pressure regulating valve 3 maintains the pressure value within the vacuum element 1 at a relatively constant value before the pressure value on the influence channel 5 reaches a preset pressure value. Accordingly, the torque at the level of the vacuum element 1 decreases and the speed of the vacuum element 1 is able to increase, without jeopardizing the life span of the motor 2 and without experiencing any significant fluctuations in speed and/or sound intensity.

[0140] After said preset pressure value is reached, the vacuum element 1 reaches nominal functioning parameters and the controller unit preferably comprises means for connecting the vacuum element 1 to a process channel 4. Because of this, the vacuum element 1 is able to reach a relatively high speed and yield until it is connected to the process channel 4.

[0141] Preferably, said means for connecting the compressor/vacuum element 1 to a process channel 4 comprises an electrical signal generated by said controller unit.

[0142] If the system comprises a compressor element 1, said compressor element 1 can be connected to the process channel 4 immediately after the system is turned on.

[0143] Preferably, the controller unit further comprises a data communication channel for sending a control signal to said motor 2 for increasing or decreasing the rotational speed of the motor 2 if the received current parameters are not between a predetermined maximum and/or a minimum current value.

[0144] Preferably, said data communication channel can be a wired or a wireless data channel.

[0145] In a preferred embodiment according to the present invention, the rotational speed of the motor 2 is decreased according to a first pre-determined maximum speed variance graph 6 and/or increased according to a second pre-determined maximum speed variance graph 7.

[0146] In yet another preferred embodiment, the second maximum speed variance graph 7 and the first maximum speed variance graph 6 determine a hysteresis type of behavior for the speed of the compressor/vacuum element (Figure 2). Because of this the frequency of speed and noise intensity fluctuations are reduced.

[0147] In an embodiment according to the present invention, after the compressor/vacuum element 1 is connected to the process channel 4, the speed of said compressor/vacuum element 1 is relatively high and the torque is relatively low, such that the pressure at the level of the process channel 4 is influenced with a maximum yield.

[0148] Once the required pressure at the level of the process channel 4 is reached, the controller unit preferably reduces the speed of the compressor/vacuum element 1 and allows for said pressure value to be maintained. If the pressure value at the level of the process channel 4 changes, then the controller unit according to the present invention regulates the speed of the compressor/vacuum element 1 according to the first maximum speed variance graph 6 and/or the second maximum speed variance graph 7, as previously described.

[0149] In a preferred embodiment according to the present invention (Figure 3), the controller unit comprises means for translating the first maximum speed variance graph 6 to lower values and/or translating the minimum preset speed value 8 of the compressor/vacuum element 1 to higher values, if the current passing through the motor windings is higher than the maximum allowed current. Furthermore, the controller unit comprises means for translating the first maximum speed variance graph 6 to higher values and/or translating the minimum preset speed value 8 of the compressor/vacuum element 1 to lower values if the current passing through the motor windings is lower than the maximum allowed current.

[0150] Preferably said means comprises an algorithm performed by said processor.

[0151] Because of said means, the controller unit according to the present invention does not influence the speed of the compressor/vacuum element 1 directly, but the first maximum speed variance graph 6 and/or the second maximum speed variance graph 7 and/or the minimum present speed value 8, which create the speed limits between which the compressor/vacuum element 1 is allowed to function.

[0152] Accordingly the speed and sound fluctuations and kept to a minimum.

[0153] Preferably, the controller unit further comprises means of applying a tolerance selected between 0.1 - 2 A (Ampere) before translating the first maximum speed variance graph 6 and/or the second maximum speed variance graph 7 and/or the minimum preset speed value 8.

[0154] In a preferred embodiment according to the present invention, when the current passing through the motor windings is higher or lower than a maximum allowed current, the controller unit translates only one value of the speed of the first maximum variance graph 6 and/or of the minimum preset speed value 8. Because of this, a lower computational power is needed.

[0155] The present invention is further directed to a compressor or vacuum pump being provided with a pressure regulating valve 3 and a controller unit according to the present invention.

[0156] The present invention is further directed to a use of a controller unit according to the present invention for maintaining the speed of a compressor/vacuum element 1 between a first maximum speed variance graph 6 and a second maximum speed variance graph 7.

[0157] The present invention is by no means limited to the embodiment described as an example and shown in

the drawings, but such a method can be realized in all kinds of variants, without departing from the scope of the invention.

Claims

1. A method for regulating the speed of a compressor/vacuum element (1), said method comprising the steps of:

- starting the compressor/vacuum element (1);
- regulating the pressure within the compressor/vacuum element (1) by adjusting the volume of fluid flowing between a process channel (4) and the compressor/vacuum element (1) relative to the difference between the pressure value within said compressor/vacuum element (1) and a preset pressure value;

characterized in that the method further comprises the steps of:

- connecting the compressor/vacuum element (1) to a process channel (4) after the speed of the compressor/vacuum element (1) reaches a preset speed value; and
- adjusting the speed of the compressor/vacuum element (1) such that the power of the compressor/vacuum element (1) is maintained at a relatively constant value.

2. A method according to claim 1, **characterized in that**, when the pressure in an influence channel (5) is rising, said influence channel (5) being in direct fluid communication with a compressor/vacuum element (1), the speed of the compressor/vacuum element (1) is regulated according to a pre-determined first maximum speed variance graph (6).

3. A method according to claim 1, **characterized in that**, when the pressure in the influence channel (5) is decreasing, said influence channel (5) being in direct fluid communication with a compressor/vacuum element (1), the speed of the compressor/vacuum element (1) is regulated according to a pre-determined second maximum speed variance graph (7).

4. A method according to claim 2 and 3, **characterized in that** the first maximum speed variance graph (6) and the second maximum speed variance graph (7) determine a hysteresis type of behavior for the speed of the compressor/vacuum element (1).

5. A method according to claim 1, **characterized in that** the method further comprises the steps:

- providing a pressure regulating valve (3) on an

influence channel (5), said influence channel (5) being in direct fluid communication with a compressor/vacuum element (1);

- keeping the speed of the compressor/vacuum element (1) relatively constant until the preset pressure value of the pressure regulating valve (3) is reached; and after said pressure value is reached:

- increasing the speed of the compressor/vacuum element (1) in accordance with the first maximum speed variance graph (6); and/or
- decreasing the speed of the compressor/vacuum element (1) in accordance with the second maximum speed variance graph (7).

6. A method according to claim 3, **characterized in that** the second maximum speed variance graph (7) does not reach a minimum preset speed value (8) of the compressor/vacuum element (1).

7. A method according to claim 1, **characterized in that** the preset pressure value is less than 600 mbar, more preferably less than 500 mbar and most preferably is approximately 400 mbar.

8. A method according to claim 5 further comprising the steps:

- measuring the current passing through the motor windings;
- comparing said measured current with a maximum allowed current;
- if the measured current is higher than the maximum allowed current then the speed of the motor is decreased according to the first maximum speed variance graph (6) or the second maximum speed variance graph (7).

9. A method according to claim 8 further comprising the steps:

- if the current passing through the motor windings is higher than the maximum allowed current, the first maximum speed variance graph (6) or the second maximum speed variance graph (7) is translated to lower values and/or the minimum preset speed value (8) of the compressor/vacuum element (1) is translated to higher values; and/or
- if the current passing through the motor windings is lower than the maximum allowed current, the first maximum speed variance graph (6) or the second maximum speed variance graph (7) is translated to higher values and/or the minimum preset speed value (8) of the compressor/vacuum element (1) is translated to lower values.

10. A controller unit, being configured to regulate the speed of a compressor/vacuum element (1), the controller unit comprising:

- a data communication interface for receiving parameters relating to the current of a motor (2) driving the compressor/vacuum element (1);
 - means of comparing the data received from said motor (2) with a predetermined current value saved within a database;
 - a pressure regulating valve (3) intended to be mounted on an influence channel (5), said influence channel (5) being in direct fluid communication with the compressor/vacuum element (1), said valve (3) regulating the pressure within the compressor/vacuum element (1) by adjusting the volume of fluid flowing between a process channel (4) and the compressor/vacuum element (1) relative to the difference between the pressure value within said compressor/vacuum element (1) and a preset pressure value;
- characterized in that** the controller unit further comprises
- means for connecting the compressor/vacuum element (1) to a process channel (4) after the speed of the compressor/vacuum element (1) reaches a preset speed value;
 - a data communication channel for sending a control signal to said motor (2) for increasing or decreasing the rotational speed of the motor (2) if the received current parameters are not between a predetermined maximum and/or a minimum current value.

11. The controller unit according to claim 10, **characterized in that** the rotational speed of the motor is decreased according to a first pre-determined maximum speed variance graph (6) and/or increased according to a second pre-determined maximum speed variance graph (7).

12. The controller unit according to claim 11, **characterized in that** the second maximum speed variance graph (7) and the first maximum speed variance graph (6) determine a hysteresis type of behavior for the speed of the compressor/vacuum element (1).

13. The controller unit according to claim 10, **characterized in that** said data communication channel can be a wired or wireless data channel and/or said means of comparing the data received from said motor (2) with a predetermined current value comprises a processor.

14. Compressor or vacuum pump being provided with a pressure regulating valve (3) and a controller unit

according to any of the claims 10 to 13.

15. A use of a controller unit according to claim 10 for maintaining the speed of a compressor/vacuum element (1) between a first maximum speed variance graph (6) and a second maximum speed variance graph (7).

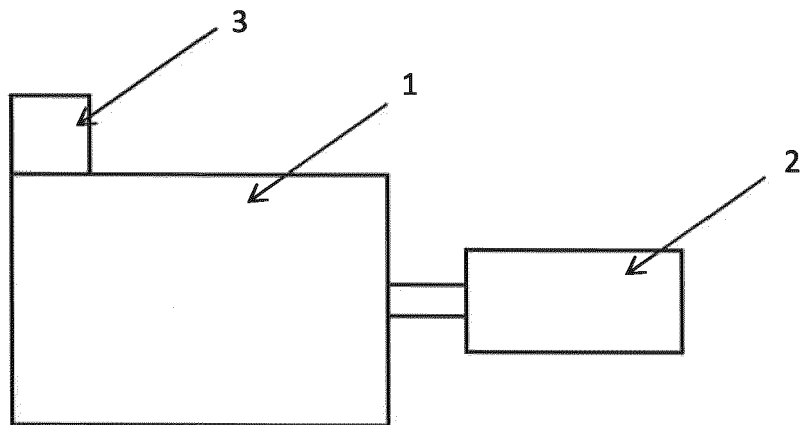


Figure 1.

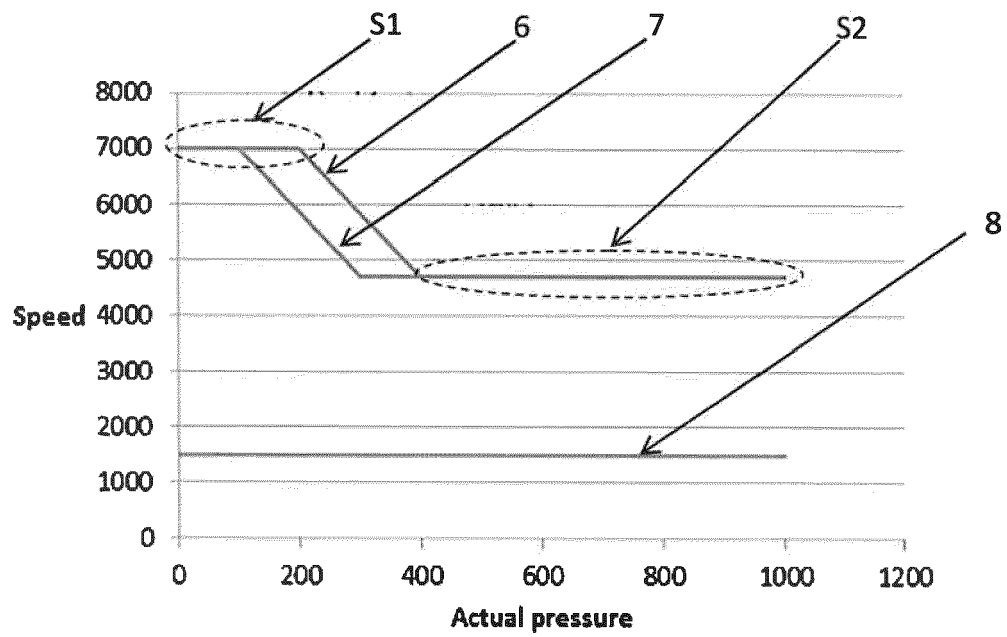


Figure 2.

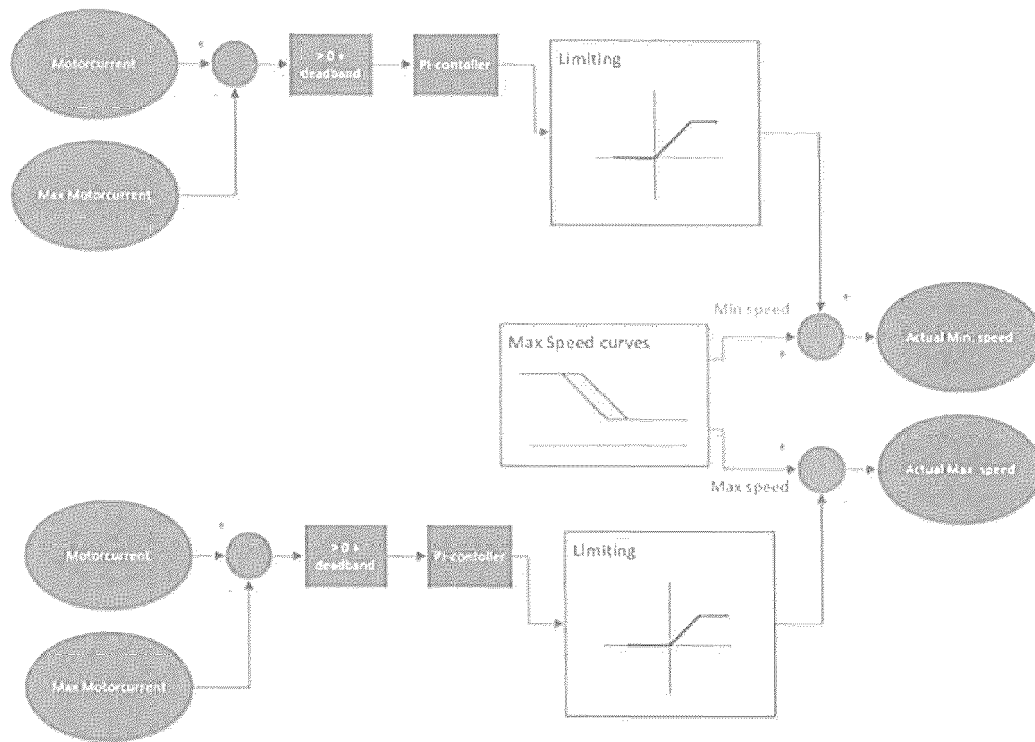


Figure 3.

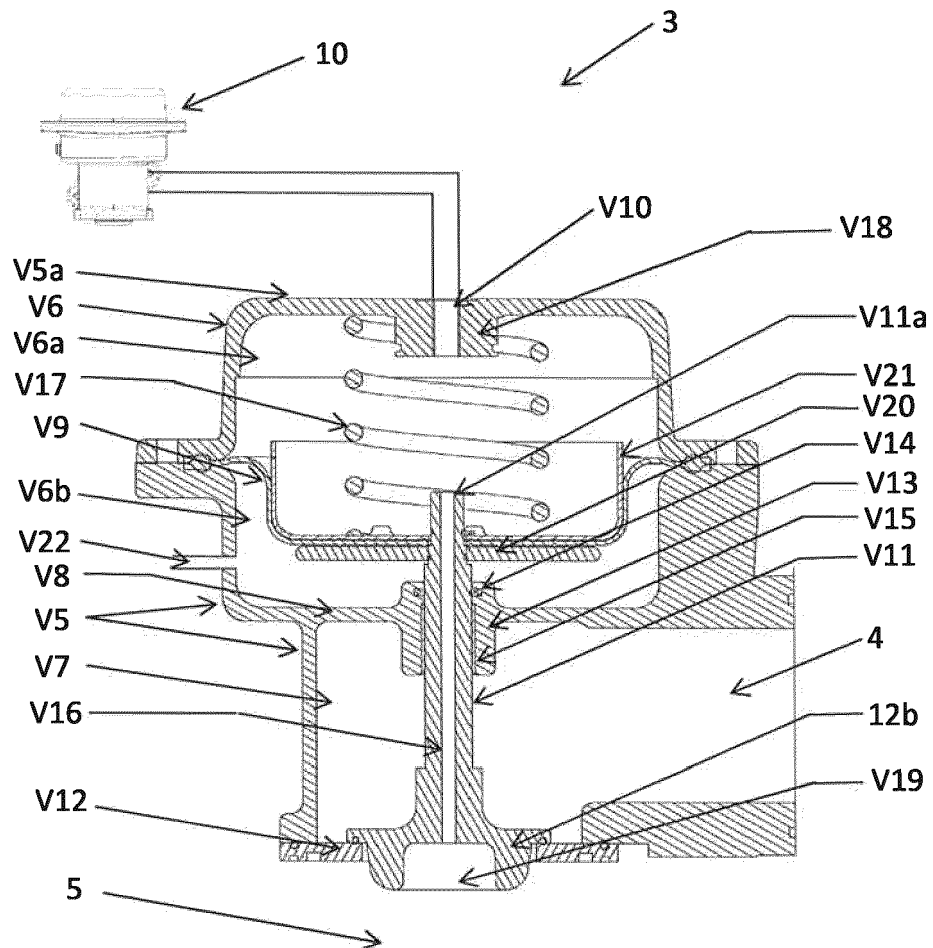


Figure 4.

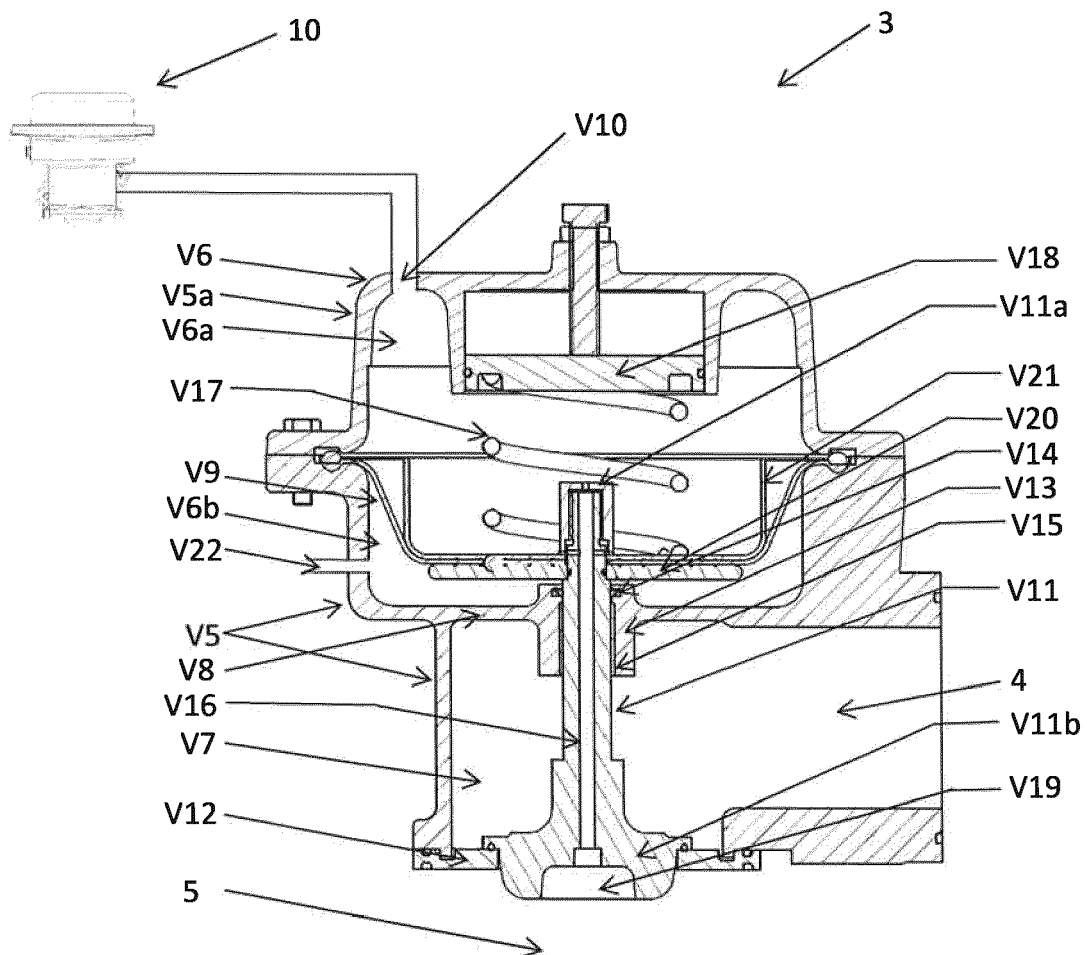


Figure 5.



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Place of search

Munich

Date of completion of the search

31 May 2022

Examiner

Durante, Andrea

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