

Control method for the acceleration of a vacuum pump, in which method the input current of the control device is limited

The invention relates to a control method for the acceleration of a vacuum pump, in particular a turbomolecular pump.

Vacuum pumps, such as turbomolecular pumps, have a rotatably supported rotor shaft in a pump housing. The rotor shaft carries at least one rotor that in the case of turbomolecular pumps comprises a plurality of rotor discs. The rotor co-operates with a stator which in the case of a turbomolecular pump is a stator with a plurality of stator discs, with the stator discs being arranged between the rotor discs. The rotor shaft is driven by an electric motor that usually is arranged directly on the rotor shaft. Further, a control device is provided that is arranged either inside or outside the pump housing and that controls the vacuum pump according to different operating parameters.

A particularly critical moment is the control of the acceleration of the vacuum pump. Here, the pump is run from standstill or a very low rotational speed to the rated speed or the operating speed at which the vacuum pump has the maximum output. Such an acceleration of a pump is often required in particular in dynamic processes. In known pumps, in particular turbomolecular pumps, a maximum current is allowed at the electric motor during acceleration. This maximum current is constant during acceleration until the rated speed of the vacuum pump is reached. When the vacuum pump is operated at the rated speed, the motor current decreases to an operating value. The same may vary depending on the quantity of gas to be conveyed and on the type of gas, but does not reach the maximum value reached during acceleration.

At times there is a demand to provide smaller, less powerful power supply unit for the vacuum pump. These are power supply units which, different from conventional power supply units, are not designed for the nominal power of the pump, but have a lower nominal power. In an attempt to meet this demand for smaller power supply units it is known to reduce the maximum current of the electric motor allowable during acceleration. It may well be possible to thereby

use smaller power supply units, but the acceleration time until the rated speed of the vacuum pump is reached becomes longer.

It is an object of the present invention to possibly reduce the increase in acceleration time also when power supply units are used that have a lower nominal power than the pump or the pump electronics, or to reduce the acceleration time when high-capacity power supply units are used.

The object is achieved according to the invention with the features of claim 1.

The present control method for the acceleration of a vacuum pump, in particular a turbomolecular pump, is based on the insight that the motor current is not the essential critical parameter with respect to a demanded downsizing of the power supply unit or a shortening of the acceleration time. The motor has to be designed in particular with regard to mechanical conditions. As a result a maximum allowable motor current is usually reached neither during acceleration, nor during the operation of the vacuum pump. Tests have shown that the essential pertinent parameter is the input current of the control device.

According to the control method of the present invention the input current of the control device is limited to a maximum value during a first acceleration phase. Thus, in the first acceleration phase, the input current rises to the maximum value. Thereafter, in a second acceleration phase, the control device is operated at the maximum value of the input current, wherein the rated speed of the vacuum pump is reached in particular at the end of the second acceleration phase. In such a control method, the technically allowable maximum current of the motor is not exceeded. As such, when a smaller power supply unit is used, the acceleration time can be reduced compared to a limitation of the motor current. Similarly, when a high-capacity power supply unit is used, the acceleration can be shortened.

It is preferred that the input current drops to an operating value in the control device after the second acceleration phase has been run through. An overload of the control device will thus not occur in normal operation even for varying types of gas or quantities of gas.

Further, it is preferred that the input current of the control device rises in the first acceleration phase. In particular, this is an increase to the predefined maximum value, wherein this increase is in particular constant. Preferably the input current of the control device thus reaches its maximum value at the end of the first acceleration phase.

It is further preferred that the motor current is constant in the first acceleration phase. In particular, this is a maximum value of the motor current that is not exceeded during operation. However, this does not have to be the maximum allowable motor current. The same may possibly even higher, as long as this is allowable in view of mechanical conditions. Preferably the motor current decreases during the second acceleration phase. The decrease in motor current during the second acceleration phase preferably corresponds to an e-function. During the operation following the second acceleration phase, the motor current drops to an operating value. The same may vary in particular in dependence on the type and quantity of the gas conveyed, but is always lower than the maximum current applied during the first acceleration phase.

The rotational speed of the vacuum pump preferably rises during both acceleration phases. Preferably the rotational speed increases faster or steeper in the first phase than in the second acceleration phase. Preferably the increase in rotational speed is linear in the first acceleration phase. In the second acceleration phase the increase in rotational speed preferably follows an e-function.

Preferably there is a marginal condition during the control method of the present invention that the system capacity is always lower than the motor capacity.

Tests have shown that in a vacuum pump without reduction of the motor current, i.e. in a method according to common prior art, the input current of the control device rises to maximally 7.3 A, while the motor current reaches a maximum value of 7.8 A. The acceleration time to the maximum rotational speed of the vacuum pump is 350 s in this case.

If, as is further known from prior art, the maximum allowable motor current is reduced to 2.8A, due to a demand for a use of a power supply unit with a lower rated power, the maximum input current also decreases to 2.4 A. However, the acceleration time is extended to 1244 s.

An exemplary test has shown that, if the control method of the present invention is used, the acceleration time can be reduced drastically to 628 s. Here, the maximum input current of the control device is 2.5 A and the maximum motor current is 2.8 A.

The following is a detailed explanation of the invention with reference to different graphs in comparison with prior art.

In the Figures:

Fig. 1 is a graph showing acceleration according to prior art at maximum motor current,

Fig. 2 is a diagram showing acceleration according to prior art at reduced motor current,

Fig. 3 is a diagram showing an acceleration according to a preferred embodiment of the control method of the present invention.

Fig. 1 illustrates a control method according to prior art which allows a maximum motor current $I_{M,max}$. At the beginning of the acceleration the motor current represented by a solid line increases to $I_{M,max}$ at a time t_1 . The motor current is then kept constant until a time t_3 . At this time, the rotational speed of the vacuum pump represented by a dotted line has reached the rated speed. Up to a time t_6 the vacuum pump then runs in normal operation, where fluctuations in the quantity of gas or the type of gas conveyed may possibly occur. This results in variations of the motor current. Further, Fig. 1 shows the course of the input current in a dashed line. The input current of the control device increases continuously from the start of acceleration t_1 and, similar to the motor current, varies during

operation between the times t_3 and t_6 in dependence on the type of gas and the quantity of gas conveyed, for example.

For a downsizing of the power supply unit, it is known to reduce the motor current. This is schematically illustrated in Fig. 2, with the motor current reduced to $I_{M,red}$. At a time t_1 the motor current thus rises to $I_{M,red}$ and is kept on that value until the vacuum pump has reached its rated speed. Due to the reduction of the motor current, the rated speed n_{max} is reached only at the time t_5 . Between the times t_5 and t_6 , the operation in which the motor current may vary is again shown schematically. Corresponding to the operation at maximum motor current, the input current of the control unit illustrated as a dashed line rises continuously from t_1 to t_5 , with the motor current being reduced to $I_{M,red}$, and then varies during operation between t_5 and t_6 .

In particular, it is also evident from the graphs in Fig. 1 and Fig. 2 that the input current of the control device does not exceed the current of the motor. Since it has further been found that, possibly due to mechanical requirements to be met by the motor, a maximum allowable current in the motor is higher than the current $I_{M,max}$, the control method of the present invention as schematically illustrated in Fig. 3 has been developed. Here, the acceleration was divided in two phases. The first phase is the period t_1 to t_2 and the second acceleration phase is t_2 to t_4 . According to the invention, in a first acceleration phase, the input current of the control device, which is shown as a dashed line, is limited to an input current $I_{S,max}$. In the first acceleration phase, i.e. up to the time t_2 , the input current of the control means constantly rises up to the predetermined maximum value $I_{S,max}$. During this first acceleration phase the rotational speed also rises continuously, but does not yet reach the rated speed n_{max} . The motor current I_m is constant during this first phase.

In the second phase the input current of the control device is limited to the maximum value $I_{S,max}$. This causes a further, although slower rise in the rotational speed of the vacuum pump until the rated speed n_{max} is reached. The rise in the rated speed follows an e-function. Tests have shown that, as is also evident from the schematic graphs, the acceleration time can be reduced to the time, when the rated speed n_{max} is reached. The maximum speed is reached at a time t_4 .

This time is earlier than the time t_6 (Fig. 2) when the maximum motor current is reduced. In normal operation between the times t_4 and t_6 the rated speed remains constant and the input current of the control device can vary.

In the second acceleration phase, i.e. between the times t_2 and t_4 , declines in particular corresponding to an e-function and varies during operation between the times t_4 and t_6 , if for example the type of gas or the quantity of gas changes.

The method of the present invention has been described above with reference to the demand for the use of a smaller power supply unit. As has been explained, in particular with reference to Fig. 3, the use of a smaller power supply unit makes it possible to reduce the acceleration time with respect to the acceleration time achieved when the motor current is reduced.

Correspondingly, when conventional power supply units are used, the method of the present invention can also be used to reduce the acceleration time as compared to the acceleration time illustrated in Fig. 1.

Claims

1. Control method for an acceleration of a vacuum pump, in particular a turbomolecular pump, having an electric motor and a control device, in which

in a first acceleration phase, the input current of the control device increases up to a maximum value $I_{s,max}$,

in a second acceleration phase, the control device is operated at the maximum value $I_{s,max}$ of the input current, and

a rated speed n_{max} of the vacuum pump is reached at the end of the second acceleration phase.
2. Control method of claim 1, wherein the input current of the control device decreases to an operating value after the second acceleration phase.
3. Control method of one of claims 1 to 2, wherein, in the first acceleration phase, the input current of the control device increases, in particular in a constant manner, to the maximum value $I_{s,max}$.
4. Control method of claim 3, wherein the input current of the control device reaches the maximum value $I_{s,max}$ at the end of the first acceleration phase.
5. Control method of one of claims 1 to 4, wherein the motor current is constant during the first acceleration phase, the motor current in particular having a constant maximum value $I_{s,max}$.
6. Control method of one of claims 1 to 5, wherein the motor current decreases during the second acceleration phase.
7. Control method of one of claims 1 to 6, wherein the motor current decreases to an operating value after the second acceleration phase.

8. Control method of one of claims 1 to 7, wherein the rotational speed of the vacuum pump increases in the first acceleration phase and in the second acceleration phase.
9. Control method of claim 8, wherein the rotational speed of the vacuum pump increases faster in the first acceleration phase than in the second acceleration phase.

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Abstract

A control method for an acceleration of a vacuum pump, in particular a turbomolecular pump, having an electric motor and a control device in which, in a first acceleration phase, the input current of the control device increases up to a maximum value $I_{s,max}$ and, in a second acceleration phase, the control device is operated at the maximum value $I_{s,max}$ of the input current.

Fig.3