The assessment parameters of the vacuum regulating device with reducing valve

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Summary

Using special reducing valve enables reducing the energy consumption of vacuum pumps. The vacuum pump may be controlled by changes in rotation speed or by switching on and off. This assignment is dealing with the problems in vacuum tank volume assessment, the values of switch on and switch off vacuum, the vacuum pump efficiency and the pressure differential on the reducing valve – the parameters affecting the period of the switching cycle.

Key words: *Milking machines, vacuum regulating, vacuum pump control.*

Introduction

Research and development in the field of milking technology is usually focused on internal links of the biotechnical system *man-dairy cow organism-milking machine-environment*. There has been a lot of success in this field, which can be documented by the existence of functional milking robots and by the fact that the process of machine milking itself gets accommodated to the individuality of the dairy cow. A considerably less attention was so far paid to energy demands of milking machines. And it is exactly these problems that recently appear in the limelight, particularly in connexion with ecological and economic aspects. Electric energy consumed in vain does not represent only increased costs for the operator, but also an unnecessary environmental load relating to the generation of electric energy. One of the weakest points from the viewpoint of energy utilization is the method of vacuum control.

Material and method

In the classical method of vacuum magnitude regulation the vacuum pump is passed through by a far greater air volume than required for the operation of milking machine. The method of vacuum control by pressure reducing valves issues from the pump characteristic at constant speed. It follows that should we wish to achieve a constant vacuum, the pump must be passed through by a constant air volume. Regarding the fact that the air volume sucked in by the milking machine is variable in time, the pressure reducing valve has to add such a volume of atmospheric air into the vacuum system that would make the sum of air volume sucked in by the milking machine and pressure reducing valve per unit time constant. It further follows that the vacuum pump goes on working at full performance with no regard to the actual consumption of air by the milking machine.

This is the reason why a unit has been designed for vacuum control, in which no atmospheric air would be additionally sucked in. The vacuum pump is passed through only by air from the milking machine, and its operation is controlled in dependence on the instantaneous consumption of air. The unit is illustrated in the figure 1. The vacuum pump set is connected directly to the large-volume air-chamber (big air-chamber). The connection tubing between the pump and the big air-chamber is provided with a back-pressure valve to prevent reversed motion of the pump when the electric motor is switched-off and thus undesirable suction of air occurring due to the action of vacuum from the big air-chamber. The big air-chamber vacuum is maintained by the pump within a selected range p_{n1} to p_{n2} ($p_{n1} > p_{n2}$) so that the minimum value (p_{n2}) is higher than the working vacuum in the milking machine (p_{np}) (Figure 2).

This function is then provided by the vacuum transducer which scans the instantaneous value of vacuum in the big air-chamber and controls the contactor of vacuum pump electric motor via the electronic control member. The contactor would switch-on when vacuum falls to the minimum value

1-electric motor;
2-vacuum pump;
3-big air chamber;
4-pressure reducing valve;
5-small air chamber;
6-vacuum probe;
7-back-pressure valve;
8-electronic control unit;
9-contactor.

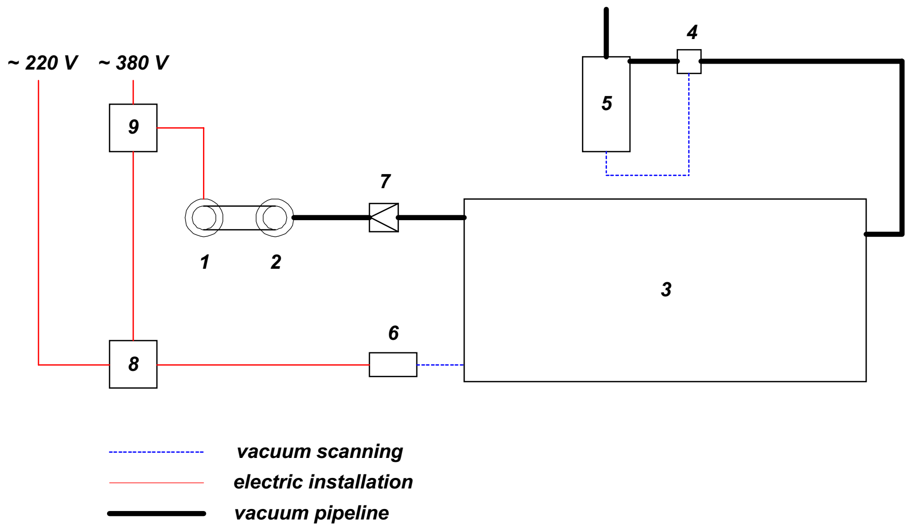

Figure 1. Functional diagram of unit with pressure reducing valve.

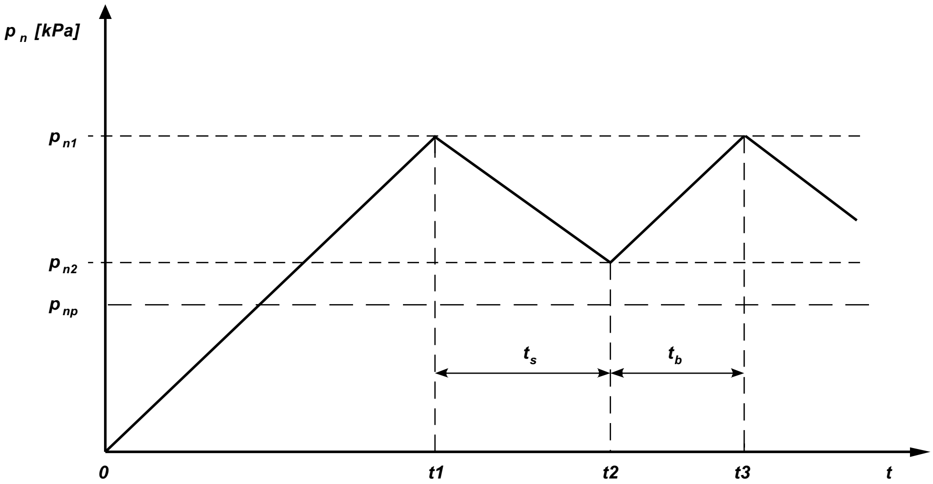

Figure 2. Vacuum control in big air-chamber

p_{n1} – *switch-off vacuum;*
p_{n2} – *switch-on vacuum;*
p_{np} – *working vacuum in milking machine*

(p_{n2}) and switch-off after the maximum adjusted value (p_{n1}) has been reached. This means that the pump operation is not continual; there are alternating time intervals when the pump is in / off the operation. These time intervals depend on pump efficiency, volume of big air-chamber, range of pressures between the contactor switching ons and offs, and on the instantaneous air flow sucked from the milking machine into the big air-chamber. There is a special pressure reducing valve inserted between the big air-chamber and the proper vacuum distribution system, with a small air-chamber whose task is to reduce the variable vacuum from the bih air-chamber to the adjusted value p_{np} and to ensure at the same time its stability. The valve was designed by the author and its prototype manufactured in workshops of the Department of Agricultural, Food and Environmental Technology at the Faculty of Agronomy, Mendel University of Agriculture and Forestry in Brno; its principle and technical solution are protected by patent.

The goal of the measurements was to assess the effect of individual variables on the regime of operation of the proposed equipment and to define their optimum values. Individual variants of measurements were made by an air-flow meter connected onto the input of the control unit and by its gradual opening to adjust the increasing values of air-flow rate. Each of values adjusted in this way was measured for time intervals when the vacuum pump was in / off the operation with simultaneous measurements being also made for vacuum values. The vacuum pump employed in the tests was Model DVL 220 with an output of 7.5 $dm^3.sec^{-1}$ (450 l / min.).

Results

The very first measurements to be carried out were those concerning the value of switch on / off vacuums. We know from experience that vacuum pump input power is increasing in linear way with the increasing vacuum at a simultaneous reduction of pump performance It followed from the dependences that the difference between working pump vacuum occurring within the chosen range $p_{n1} - p_{n2}$ and working vacuum in the milking machine p_{np} should be as small as possible The larger is the difference, the lower is the vacuum pump efficiency.

The first measurement was focused on the determination of minimum difference between the switch-on vacuum p_{n2} and the working vacuum in the milking machine. It was found out that if the difference drops below 2 kPa, the vacuum fluctuation in the milking machine is increasing. This is why the value was proposed to be 3 kPa.

Other two factors (volume of big air-chamber and difference between switch on / off vacuums) have a fairly similar impact on the operation regime. Since an increase in the difference between switch on / off vacuum values is undesirable, it was adjusted to 5 kPa and an influence was studied of the volume of big air-chamber on the length of time intervals between the vacuum pump switch-ons (t_b) and offs (t_s) in dependence on air-flow

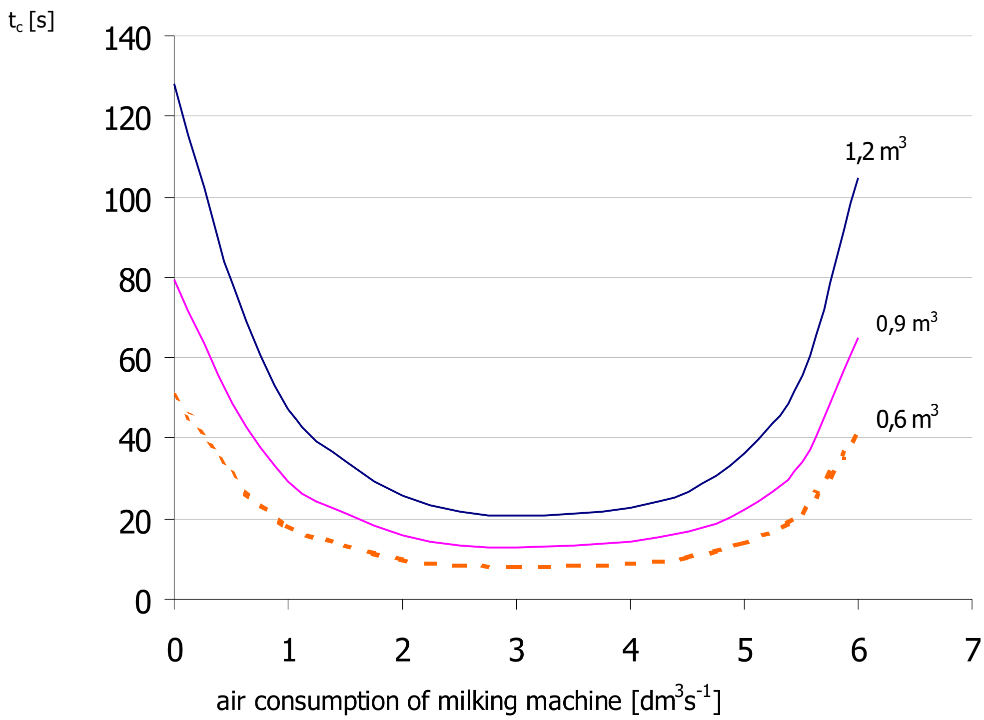

Figure 3. Dependence of switch-on cycle length on air-flow rate at different volumes of big air-chamber.

rate. There were three sizes of air-chamber used in the experiment: 0.6 m^3, 0.9 m^3 and 1.2 m^3. ¨The time interval t_b (t_s) is increasing (decreasing) with the increasing air-flow rate. In order to make a complex assessment of both time intervals, a switching cycle time (t_c) was used, for which it holds that:

$$t_c = t_b + t_s.$$

The measured values are illustrated in figure 3. The switching cycle interval reaches minimum at the moment when the time intervals t_b and t_s are equal. The condition occurs at the flow rate of 2.9 $dm^3.sec^{-1}$ (174 l / min.) regardless of the volume of the big air-chamber. At using the big air-chamber of 0.6 m^3, 0.9 m^3 and 1.2 m^3, the minimum switching cycle will be 8.3 sec, 13.2 sec and 21.4 sec, respectively.

Conclusion

The above measurements evidenced functionality of the control unit with pressure reducing valve within the whole range of vacuum pump efficiency. A minimum difference was assessed between the switching-on vacuum and working vacuum in the milking machine. For the given installation it should be 3 kPa. Also, minimum intervals of switching cycle were determined for different volumes of big air-chamber. From the viewpoint of vacuum pump set operation the number of switching cycles per minute should not exceed 2 or 3. This requirement is corresponded to by a volume of 1.2 – 1.5 m^3 provided that the difference between the switch on / off vacuums is 5 kPa. The effect of a larger difference between the switch on / off vacuums was not tested as the change would have impaired the pump efficiency.

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