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Using the Vacuum in Handling Tasks in the Context of Operating Cost Savings

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Abstract The paper analyzes the conditions of one-sided gripping using vacuum suction cups in automated operation. By way of example, it describes ways to save operating costs by modifying control algorithms for such solutions. Describes ways to avoid excessive energy losses in vacuum manipulation tasks.

Keywords: *one-sided gripping, handling tasks, operating cost, vacuum*

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1. Introduction

Operating costs of a company that deals with the automated operation of applications that use vacuum as a handling tool for manipulation objects (O_M) can be judged in terms of acquisition costs for its implementation, but in particular in terms of its operating costs.

Acquisition costs for such applications can be judged from a variety of perspectives, depending on the complexity of the manipulation task. However, it is always a one-off cost, which will ultimately be reflected in the price of production. Average acquisition costs will mainly affect the vastness of O_M, when the number of suction cups used and the associated ejectors are related to its size and complexity.

The operating costs will then depend, in particular, on the way the vacuum generator is used, that is, the distribution of the vacuum generating times.

2. One-sided Gripping

In order to understand the nature of the problem, we need to know some of the aspects that arise from applying the vacuum to performing manipulation tasks.

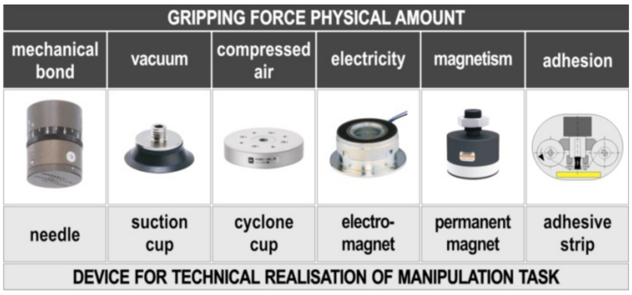

Figure 1. Realization of one-sided gripping and its physical nature

Handling tasks falling into this category are among the tasks utilizing one-sided grip of O_M. In addition to vacuum, other methods of fixation the O_M are often used for these applications. O_M in these applications are objects whose properties are for some reason specific (fabrics, perforated or non-surface objects, flat-faced objects, and others). Methods of one-sided gripping of the O_M from the point of view of the physical nature of the gripping force are illustrated in Figure 1.

3. Operating Cost

Users of vacuum-based applications often do not aware that this technology together with blowing up surfaces accounts for up to 70% of total compressed air consumption in production facilities, Fig. 2. This high percentage results largely from the improper use of vacuum gripping effectors during manipulation tasks.

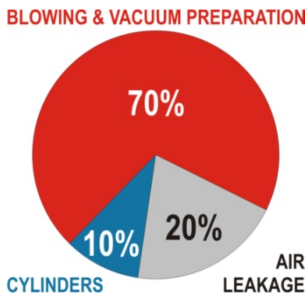

Figure 2. The proportion of compressed air consumption when used in automated operation [6,7], *edited by the authors*

The vast majority of such tasks are realized in a way that the ejector is active throughout the handling time, Figure 3. In the circuit diagram of Figure 3 with the 3/2 NC solenoid valve (EPV01) provides control of the compressed air flow through the ejector (E01), which creates a vacuum under the suction cup (SC01). In order to ensure a sustained power action of the suction cups on the O_M, it is necessary to ensure a continuous flow of air through the ejector.

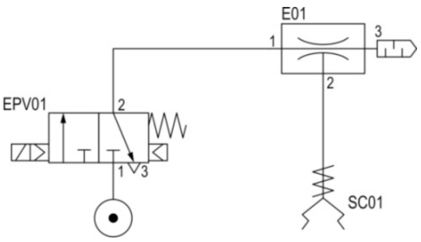

Figure 3. Simple connection for ejector and suction cup

Ejector inherently generates a vacuum only if the compressed air flows at a certain pressure. Air consumption (air flow rate per unit of time) is increasing with increasing compressed air pressure at the inlet to the ejector needed to produce the necessary vacuum quality, Figure 4.

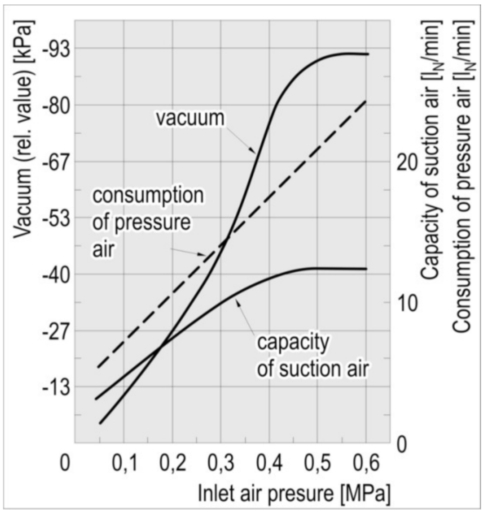

Figure 4. Features of single-stage ejector [6,7], *edited by the authors*

If we consider the manipulation task, which lasts 15 seconds, according to the diagram at an input pressure of 0.5 MPa, the volume of the consumed air is equal

$$V = Q_{CE} \cdot t\left[\mathrm{l_N}\right] \quad (1)$$

where $\boldsymbol{V}$ is the volume of compressed air used at the given pressure, $\boldsymbol{Q_{CE}}$ is the value of the air flow through the ejector at the assumed pressure and $\boldsymbol{t}$ is the duration of the air flow through the ejector. In our case, the volume of air consumed will be deducted from the one-stage ejector diagram roughly 22 l_N/min, that's in 15 seconds 5,5 l_N. We use so much air to grip and transfer O_M during the handling task. Let's assume that the manipulation task is done once in 1 min. During a 8-hour shift, 60 x 8 = 480 manipulations were performed, which in total represents the total air consumption of 2,640 l_N of air per ejector. At a price of 1 cubic meter of compressed air, approximately EUR 0.04, the handling costs for one operational shift amount to approximately EUR 0.1056. Of course, the projected flow through the ejector must correspond to the needs of the suction cup of a certain diameter and shape (the diameter of the deep or bag suction with respect to the evacuation time will have to be smaller than would be the case, for example, flat suction cup).

In practice, however, manipulation tasks do not take place with a single suction cup. If for each suction cup (given its volume and the target value of the evacuation time) one ejector with the given characteristics is assigned (Figure 4), if the total number of 1000 suction cups with ejectors is used, the cost is already raised to EUR 105,6 per shift. The total annual costs would then amount to approximately 52 x 5 x 105.6 EUR = 27.456 EUR for one-shift operation.

The efficiency of the application with respect to the consumed energy also affects the distance between the vacuum generator and the suction cup. From this point of view, it is most rational to engage the ejector in one block with a suction cup, Figure 5.

The volume of vacuum required to form the gripping force between the suction cup and the O_M does not only represent the volume under the suction cup. If the standard connection is used (Figure 3), an additional consumption of the vacuum volume required to remove the atmospheric air from the hoses and other peripheral components (vacuum filter, vacuum gauge, vacuum switch, etc.), Figure 6.

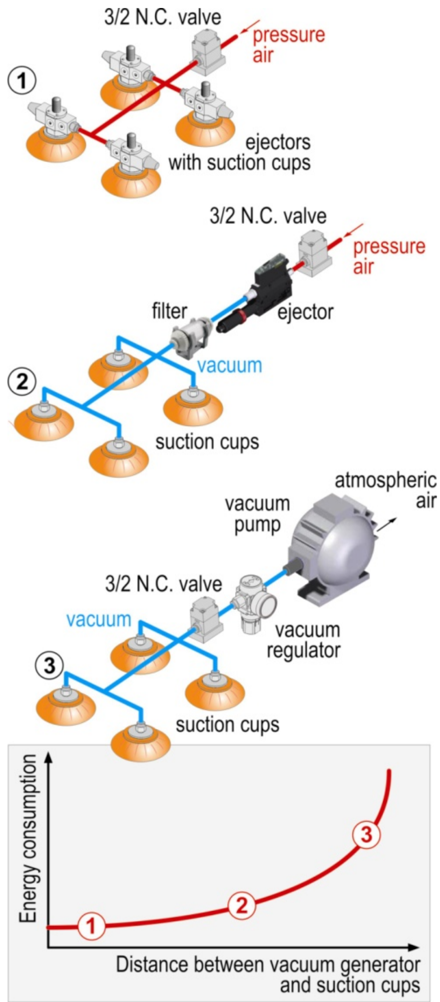

Figure 5. Dependency power claim according to choices methods location of suction cups and vacuum source [5], *edited by the authors*

In Figure 6 red color shows the total volume of the vacuum, which is necessary to produce a sufficient force effect from the suction cup to the O_M. This means that for a sufficiently short evacuation time the ejector must have a sufficiently high flow rate while preserving the quality of the vacuum. This can be done with only 2-stage ejectors, Figure 7, or 3-stage ejectors, Figure 8. Of course, the amount of compressed air flowing through the ejector is increasing with the ejector suction power.

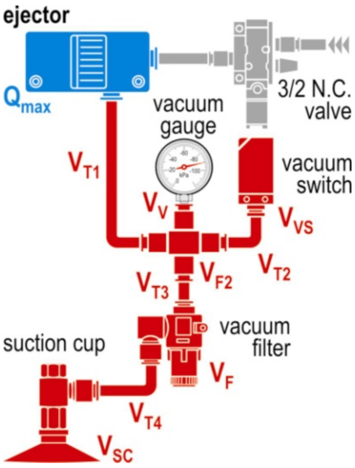

Figure 6. The volumes of the individual parts of the circuit with the ejector and the suction cup [1], *edited by the authors*

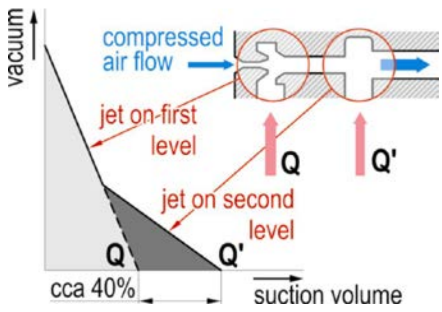

Figure 7. Volume ratios on a 2-stage ejector [6,7] , *edited by the authors*

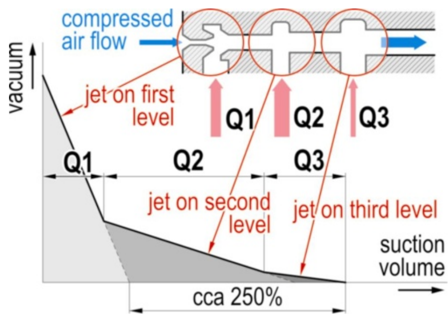

Figure 8. Volume ratios on a 3-stage ejector [6,7], *edited by the authors*

Therefore, when considering the manipulation task using a vacuum suction cup (and the associated ejector), it is preferable to join according to the diagrams in Figure 9.

Both schemes use the principle of "locking" the vacuum between the check valve in the outlet channel of ejector (E01), control valves (EPV02, resp EPV03) and suction cups (SC01). This allows the vacuum to be activated only by a time-limited impulse (e.g. 1 sec) on the control valves (activation with 3/2 N.C. valve EPV01 or lower position of the 5/3 valve with closed center - EPV03), which will ensure a sufficient connection O_M and suction cup for the remainder of the handling cycle. To release the gripping force of thesuction cup, either 2/2 N.C. valve EPV02 or second side of the 5/3 valve EPV03. To release the O_M, a short control pulse is enough (e. g. 1 sec).

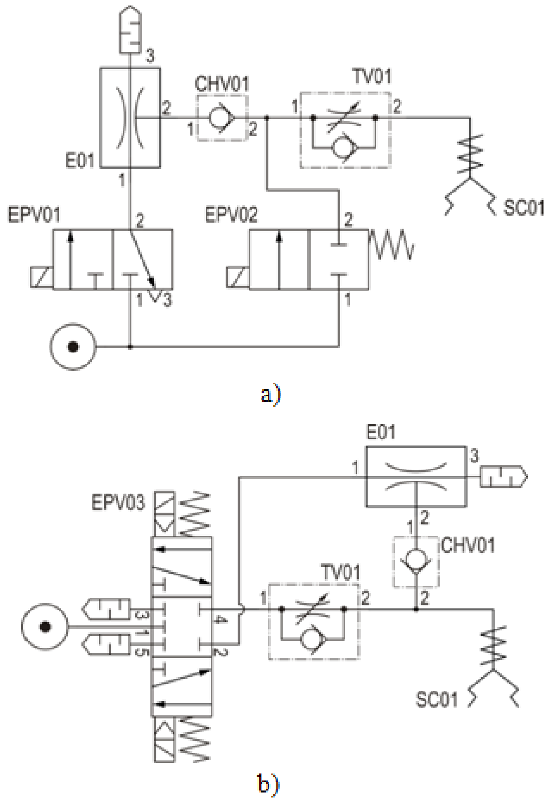

Figure 9. Circuit diagram saving air in the development of vacuum

This reduces the active time of the ejector from 15 to 1 second, which reduces operating costs per year to approximately EUR 1,830.4. It should be emphasized that part of the running costs will be spent to supplement the circuit with the necessary components.

A specific problem in saving operating costs is often the case of unoccupied suction cups, Figure 10.

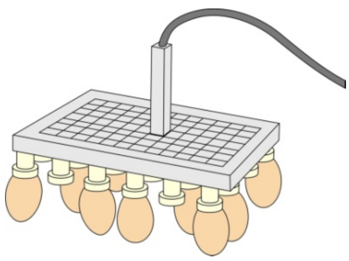

Figure 10. Unoccupied suction cups powered from a single ejector [2,3]

In this case, there is a risk that OM will not be securely fixed during the entire manipulation task. If, for example, one of the suction cups is unoccupied and all are powered from one ejector threatens that objects on the other suction cups will be retained by a lower fixed force and therefore threaten to escape.

Of course, the maximum amount of compressed air flows through the ejector, which increases both air and operating costs.

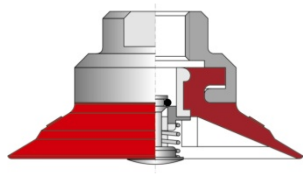

Figure 11. Special treatment of the suction cup with a check valve

Figure 12. Vacuum saving valves [6,7]

The solution offered by either the suction cups, which are provided with a check valve, Figure 11, or vacuum saving valves, Figure 12.

4. Conclusion

One-sided gripping of objects using vacuum suction cups is a sensitive problem for every user. When designing such applications, it is necessary to handle calculations when choosing suction cups and ejector, but for large applications (applications with a large number of ejectors and suction cups), it is also very important to choose the control cycle of ejector activation. Consumption of compressed air and its associated production costs represent considerable costs for running the application. As indicated in the conrtibution, it is worthwhile to analyze a particular application, and from its results choose the correct method of the activation cycle during the manipulation task. It saves not only the user's resources, but ultimately reduces the overall burden on the environment.

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