Vacuum generation for handling technology: mobile, autonomous and energy efficient

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In automated production systems handling is a key technology. Especially for gripping and clamping of workpieces, vacuum automation plays an essential role in all industry segments. Core part of a vacuum gripping system is the vacuum generation. Pneumatically driven vacuum generators are widespread in the handling technology. Due to the technological development there are also new tasks and challenges, because in future applications there is a trend that compressed air will hardly be available. In this paper it is presented, how electrically driven vacuum generators can increase the energy efficiency of mobile handling systems and also in addition to that can influence new forms of work, like human-robot collaboration.

Keywords: Vacuum Handling, Automation, Human-Robot Collaboration, Energy Efficiency
Target audience: Pneumatics, Mobile Applications, Components

1 Introduction

Automated production is the key for marketable products. With automation technology it is possible to cut process costs, to increase numbers and productivity and finally to increase quality. This leads to a high efficient production and better, cheaper and quicker available products at the end. That is why the market for automation solutions is increasing continuously. Statistics of the world robotics report 2016 /1/ are showing a steady increase of the annual supply of industrial robots. The main applications of industrial robots are handling operations.

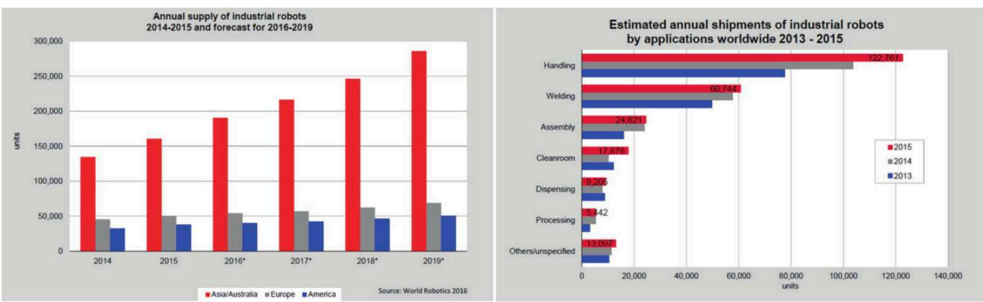

Figure 1: annual supply of industrial robots (left), estimated annual shipments of industrial robots by application (right) /1/

In general, the end-user of automation solutions is interested in process-safety with suitable accuracies without influencing or even losing the workpiece, high availability of facilities, short cycle times and less investments and running costs. Therefore, in combination with upcoming trends in production technology, there are new challenges for vacuum handling technology in the future.

2 Phases of a vacuum handling process

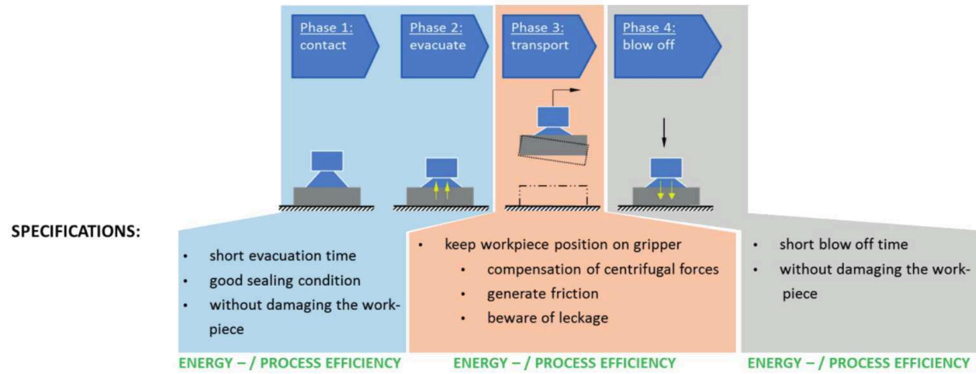

Figure 2: core phases of a vacuum handling process

To ensure the shown customer value during a handling process, first of all the workpiece has to be placed quickly with suitable process safety at its target position. Therefore, the suction cups must be supplied with the required fluid power. This is influenced by short evacuation times, good sealing conditions, less leakage, short hoses and less flow losses within the vacuum gripping system. This is also important regarding energy efficiency and operating costs.

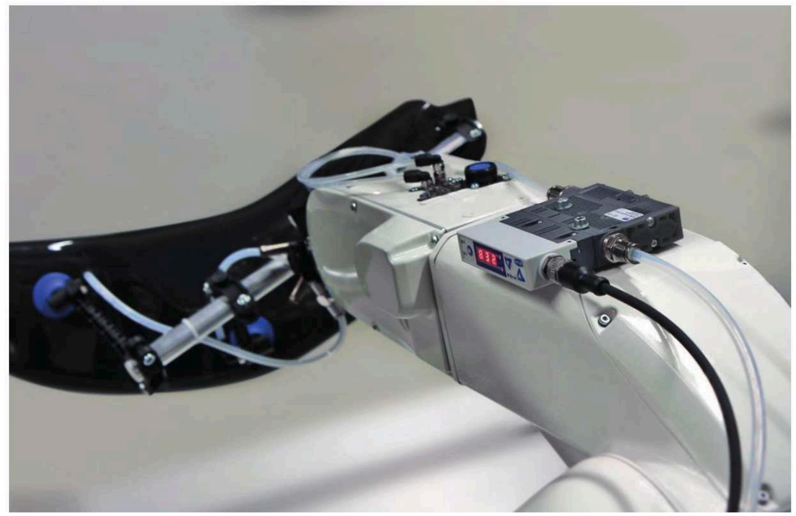

Figure 3: vacuum gripping process with robot, ejector, suction cups and workpiece

3 Energy efficiency of vacuum handling systems

Energy efficiency in the field of vacuum handling technology is still low, due to the transformation of electrical energy into compressed air and then the transformation of compressed air into vacuum. Besides the vacuum generation, also the further infrastructure, the workpiece, the suction cups and of course the process parameters are influencing the energy consumption of a vacuum gripper in general, as mentioned above.

The energy efficiency of vacuum handling systems is still relatively unexplored, even if there are first research projects to this topic (e.g. /2/ and /3/). Pneumatically driven vacuum generators as a key component were already in the focus of research projects (e.g. /4/ - /10/). Due to features like air saving function and others to influence the handling process, these research results are not meaningful enough to evaluate entire handling processes under real production conditions in use.

4 Trends in the field of automated production

Nowadays, the borders between fully automated processes and manual handling applications done by workers become blurred. In place of many activities in this case, there is the topic "human-machine-interaction". This means, that workers and machines are working (temporarily) together in the same working space. (e.g. /11/). The robots used for this kind of application are small and with a lightweight construction. In the field of "autonomous warehousing", they were even used on mobile platforms to handle goods in a stock for example.

In the scope of vacuum handling there is one important restriction: in mobile applications it is not possible to carry a compressed air line. With other lightweight robots with included sensors it is also not possible to mount a compressed air line at the robot, because this would influence the sensors and this would interfere with the function of this kind of robots.

So when operators of handling technology want to use vacuum handling technology and its benefits in the future, new approaches and technologies are needed to generate vacuum without compressed air.

A first technology study carried out by Schmalz /12/ in 2013 showed approaches with no external energy supply for handling applications. Core element was a so called "push-push-mechanism" including a piston which is actuated by the movement of the robot in vertical direction, when the gripper is placed on the workpiece. To place the workpiece at its target position, the mechanism has to be actuated again. This solution worked well by handling of airtight rigid workpieces without leakage. However, for an industrial use there are other solutions necessary, because in the case of leakage or other effects influencing the vacuum handling process safe processes are needed.

5 actual solutions

Before mobile robot platforms came on to the market, users believed that electrical driven vacuum generators only can be used in handling solutions, if the performance concerning vacuum and flowrate is comparable to pneumatically driven standard vacuum generators based on the venturi principle.

In Figure 3 it is shown, where standard vacuum generators can be placed at a robot or vacuum gripper in general.

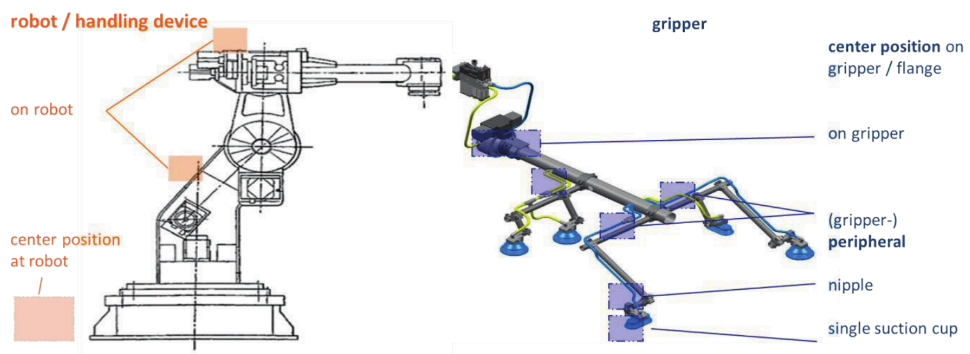

Figure 4: possible positions for vacuum generators on a robot (left) or a gripper (right)

The closer a suction cup is placed to the vacuum generator, the more the size and weight of a vacuum generator affects the moment of inertia and the total weight of the gripper. An additional benefit of placing the vacuum generator near to the suction cup is the reduced needed airflow to manage the handling solution. If the suction cup is near to the vacuum generator less inner volume of the hose has to be evacuated compared to when the distance between cup and generator is greater and if more suction cups are supplied with vacuum. As mentioned in figure 4, standard electrical driven vacuum generators like pumps are not suitable for a usage directly on the gripping system. They can only be placed in a central position nearby the robot due to the weight and performance discussion (as mentioned in figure 3).

However, this only applies if the evaluation of the performance is based on the maximum air flow rate at free flow. As mentioned, a correspondingly great airflow is necessary to achieve short evacuation times and based on that short cycle times in the application. But if the volume that should be evacuated will be reduced by reducing the inner volume of suction cups, hoses and other components, also smaller electrically driven vacuum generators like membrane pumps are able to achieve comparable or at least acceptable evacuation and cycle times. The smallest pneumatically driven vacuum generator based on venturi nozzles are generating a suction flow of about 35 l/min at free flow. Small lightweight membrane pumps, which are generally suitable for a vacuum application nearby the suction cup, can generate a maximum airflow of about 50% of the mentioned value.

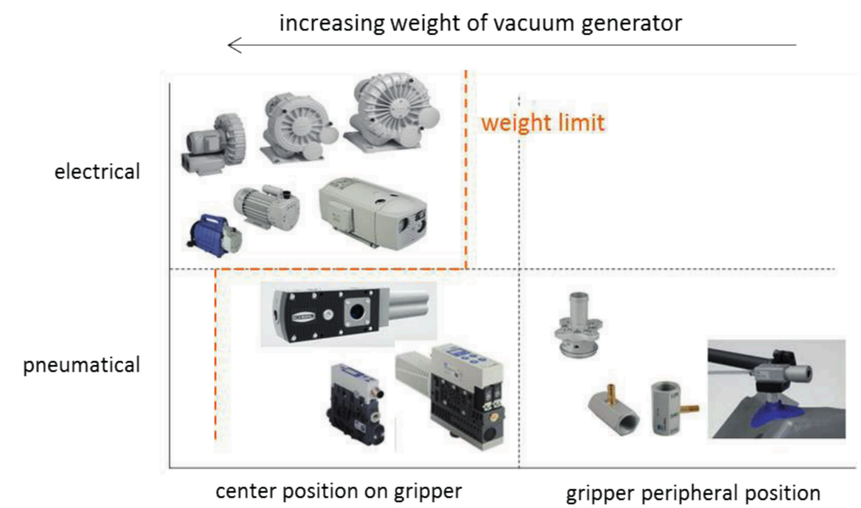

Figure 5: Portfolio of standard vacuum generators

Especially if the usage of compressed air is difficult or even impossible, there are new applications possible by using electrically driven vacuum generators which were not possible so far. Furthermore, new applications are leading to new discussions concerning energy efficiency and necessary airflow-rates in "standard applications", were the usage of compressed air is generally possible. So also in these "standard applications" it is now possible to reduce the airflow rate in free flow conditions, if this does not lead to a loss of performance and the application can be realized with similar conditions as the standard solution.

Figure 6: Mobile platform with robot (left – source: KUKA Aktiengesellschaft), Schmalz-CobotPump – electrical vacuum generator for CoBots (right)

In standard vacuum ejectors based on the venturi principle, compressed air is flowing with sonic speed. The flowing conditions in ejector nozzles are partly leading to tremendous noise emissions. When there is no additional silencer mounted on the ejector, this can lead to hearing impairment of workers. That is why the usage of silencers is mandatory by law - depending on the value and application. Besides the reduction of noise, silencers are also influencing the performance, because a silencer is a kind of flow resistance.

In the applications mentioned above, where worker and robot are working together, a pneumatically driven vacuum ejector with a high noise emission level could be dangerous in the immediate proximity of the worker, due to safety reasons at work and accident prevention regulations. Also in such conditions, small electrically driven vacuum generators have benefits in comparison to standard ejectors, because noise emission levels of membrane pumps are lower than those of ejectors, because there are no high flow rates in membrane pumps.

6 Conclusion and Outlook

In automated production processes, pneumatically and electrically driven vacuum generators are used. However, standard electrically driven vacuum generators have a considerable bigger size and weight than ejectors with a comparable performance. That is why these kinds of electrically driven vacuum generators cannot be mounted directly on a gripping system. Normally, these generators are placed nearby the robot or handling device. When placed as described above, vacuum hoses are necessary, to supply the suction cups on the gripper system with the vacuum generated besides the robot. This leads to greater volume inside the hoses and other components, which must also be evacuated during each cycle of the handling process.

In mobile applications, like they were mentioned in this paper, it is not possible to use this kind of vacuum generation – there are other approaches necessary.

At first there should be decided, which electrically driven principle is suitable for a handling application with a vacuum gripping system with a sufficient vacuum level and a highest possible airflow rate. Basically, the air flow rate at free flow is not an important value in an application, it is just necessary that short evacuation times and at the end short cycle times can be achieved. That why also smaller electrically driven vacuum generators can be used, if the performance in the application is comparable or acceptable in comparison with the standard solution.

The closer a suction cup is placed to the vacuum generator, the less is the amount of the volume inside the hoses, suction cups and other components, which must also be evacuated. Especially in mobile applications this is important, because gripping systems can be build smaller and with less weight. This is also in the focus of future work concepts, like human-machine-interaction, where workers and robots are working together in one work place without protection devices.

These kinds of applications and depending on these applications the need for mobile vacuum technology will increase tremendously. This is hardly possible by the use of pneumatics, therefore electrically driven vacuum generators are necessary. These are now ready to the market.

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