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REDUCING THE CARBON FOOTPRINT IN THE USE OF COMPRESSED AIR IN AUTOMATION

Production process projects are constantly confronted with the level of ecological burden (the so-called carbon footprint) of a specific technology. Since automated production is largely realized using compressed air, the question arises as to what extent the production and use of this medium burdens our environment. During the energy audit of the operation, it is possible to determine a number of areas in which, with the right solution, interesting results can be achieved in saving compressed air.

The article offers an overview and indicates the possibilities of solving the uneconomical handling of produced compressed air, for example by using tools provided by manufacturers of pneumatic components.

The information presented in the article is an overview.

Keywords: *compressed air; energy audit; compressed air saving; means for monitoring.*

Fig.: 7. References: 12.

Urgency of the research. The need for energy is a permanent phenomenon in industrial production. At the same time, its consumption and production are not always in proper balance (Fig. 1) [1].

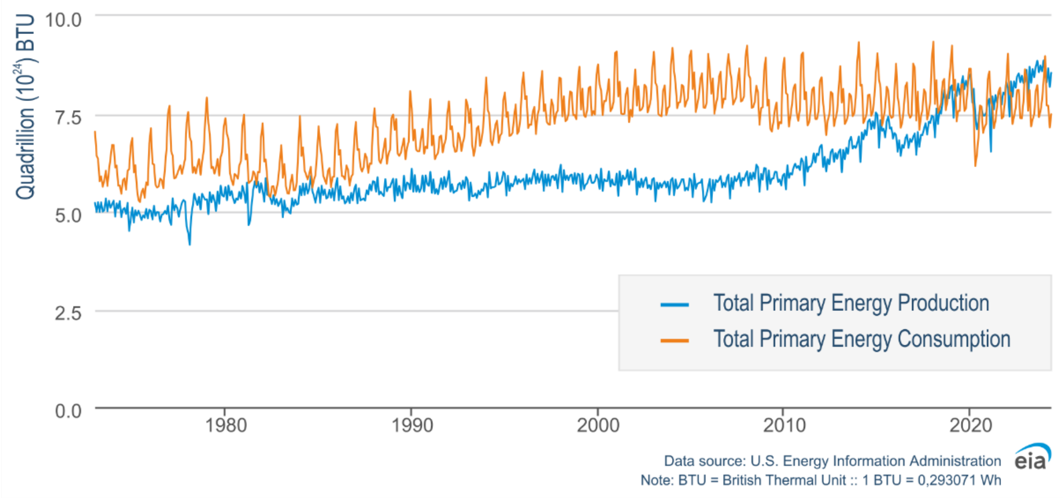

Fig. 1. Primary Energy Overview

Source: edited by author [1].

In industrial sectors, electricity is the most frequently used energy. Various types of primary energy are used for its production, until recently they were solid fossil fuels, mainly coal, today their dominance is being strongly overtaken by the use of natural gas. The use of fossil fuels, however, is connected to the fundamental problem of today, the share of carbon emissions in the production of electricity, Fig. 2 [1].

After the Kyoto Conference on Climate Change (held in December 1997), to stop global warming, individual industrialized countries, especially in Europe, began to seriously consider reducing the share of emissions released into the atmosphere (the originally intended 6% reduction of CO_2 emissions in the period between 1990 and 2010; unfortunately not yet fully achieved), the use of coal for electricity production began to be strongly suppressed. However, many countries started using natural gas as a fuel in power plants, which reduced the amount of CO_2 in the air, but not to the required extent (Fig. 2).

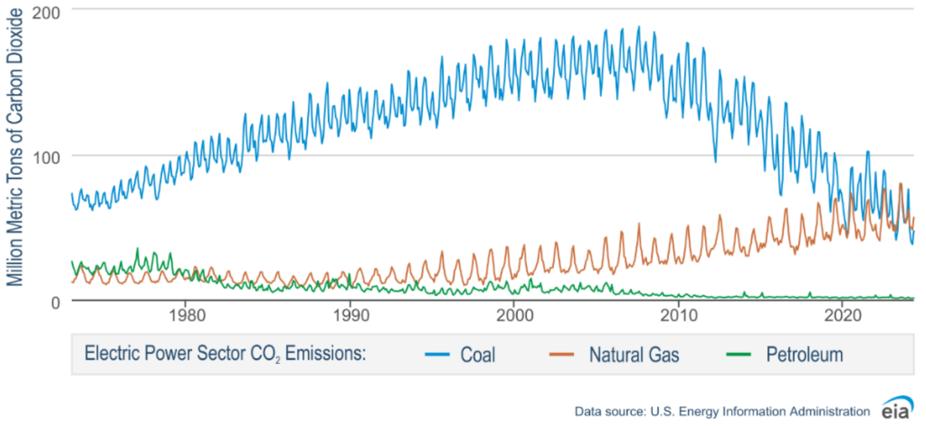

Fig. 2. Primary Energy Overview

Source: edited by author [1].

Therefore, as a possible solution, strict saving of electrical energy is offered, regardless of the sources from which it was produced. This leads modern companies to reevaluate the energy balance both from the point of view of cost and carbon footprint.

Problem statement. Since the production and treatment of compressed air is predominantly (and in the industrial sphere almost absolutely) used electrical energy and in total volume represents up to 20% of global consumptionи (Fig. 3, *a*), inappropriately consumed compressed air energy is a negative item of the total operating costs, while it also has a direct impact on ecology.

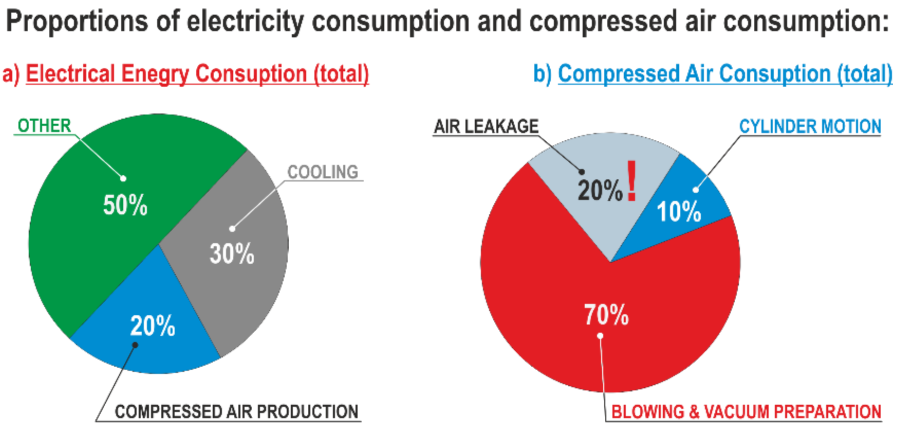

Fig. 3. Consuption of electrical energy and compressed air

Source: edited by author [2; 3].

If we analyze the second graph in Fig. 3, *b*, it is perhaps a surprising fact that only 10% of the total produced and treated compressed air is used for the force and movement action of pneumatic drives (cylinders).

Alarming is the percentage value of the share of produced compressed air attributable to leaks (leakage) in distribution systems and operating circuits. Many operators of large-scale compressed air operations solve this problem by regularly inspecting the compressed air distribution in the operation. Subsequently, they establish shutdowns in individual sections and solve leaks according to their nature.

However, the biggest "consumers" of compressed air are technologies using compressed air for blowing, possibly drying, and generating negative pressure for the implementation of manipulation tasks from the category of so-called one-sided grasping with an active suction cup.

It is quite difficult to determine the exact percentage of applications using compressed air for blowing/drying and for creating a vacuum. In terms of the total flow volumes required for blowing or drying (in some cases there will be a need to heat the used compressed air) with the volumes of compressed air for handling active suction cups, the relevant estimate is a ratio of 2:1 in favor of blowing/drying. Due to the specifics of both subgroups, it is possible to apply only some of the 12 air saving areas listed. Nevertheless, we will primarily focus on saving air during the generation of negative pressure.

Conscious companies are increasingly approaching strict energy audits as a tool to uncover areas with the potential to reduce the energy intensity of production.

In reality, there are quite a large number of areas for saving compressed air. The standard VDMA 24581 (Pneumatic fluid power - Application notes for the optimization of the energy efficiency of pneumatic systems), issued by the strongest organization uniting engineering companies operating in Germany (in the original: Verband Deutscher Maschinen- und Anlagenbau) defines a total of 12 areas (Fig. 4), in which savings can be achieved in the use of compressed air. More than half of them allow more than 15% energy savings of compressed air.

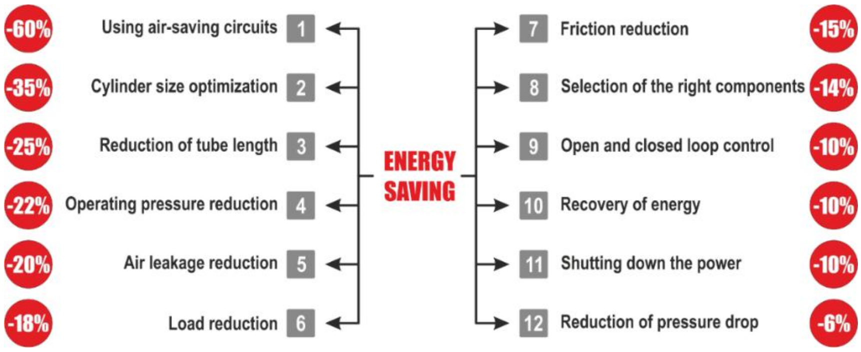

Fig. 4. Areas for compressed air energy saving

Source: edited by author [4; 5].

Analysis of recent research and publications. Based on this standard, companies producing components that use or modify compressed air (FESTO, Parker, EMERSON/AVENTICS, SMC, AtlasCopco [6]) began to offer their customers integrated services focused on saving compressed air energy. They present them either as system applications, auditing services [7], or systems enabling the monitoring of compressed air consumption in operations [8; 9] (Fig. 5, *a* and Fig. 5, *b*).

a b

Fig. 5. Means for monitoring the consumption of compressed air in operation
a – The AVENTICS Smart Pneumatic Analyzer and AF2 Series airflow sensor;
b – Air Mangement System – SMC AMS20/30/40/60 Series

Source: edited by author [10; 11].

These systems have the possibility of connection and data communication through various types of bus solutions (Ethernet, Io-Link, etc.) according to the needs and habits of the end user.

Isolation of previously unexplored parts of the general problem. In this article, we will not deal with the solution of general problems related to the energy requirement of the vacuum generated in volume vacuum generators, as it is a fundamentally different method of preparation. This means that the negative pressure that we are analyzing in our considerations is mainly created in the form of ejectors, which fundamentally need a stream of compressed air for their function (see also the Venturi phenomenon - the principle of the ejector [12]).

Research objectives. To be able to save compressed air energy, we need to determine the areas where we have the highest potential for savings, and of course, we cannot avoid constantly measuring the value of the compressed air consumed during operation and comparing it with the calculated or modeled (predicted) consumption (Fig. 6).

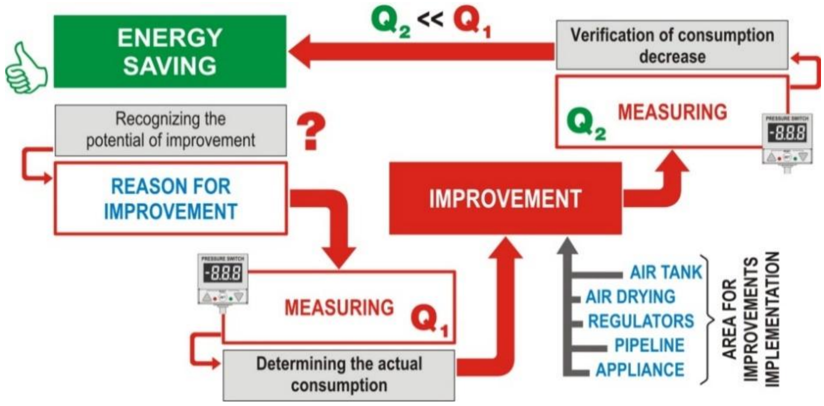

Fig. 6. Procedure for the application of the energy saving system

Source: edited by author [5].

Let us now analyze the individual areas for saving compressed air (Fig. 4).

1. Using air-saving circuits. When creating a pneumatic circuit, especially in applications for manipulation tasks with one-sided grasping with an active suction cup, it is possible to use a suitable addition to the classic arrangement of the circuit and its control so that the generation of negative pressure by the ejector does not have to be realized during the entire manipulation task (see Fig. 6).

2. Cylinder size optimization. Designers of pneumatic equipment often choose excessively robust drives in an attempt to prevent a decrease in the performance of the equipment in case of insufficient pressure in the circuit. This necessarily leads to an increase in the diameter of the piston, which increases the volume of compressed air consumed during one double stroke. This increases the operating costs of the equipment.

3. Reduction of tube length. The length of the hoses used is often not taken into account when circuits are implemented in operations. The filling volume of the hoses must also be included in the total consumption of compressed air during operation because when changing the direction of the airflow through the valve, this air must necessarily be vented. Optimizing the length of the hoses can save up to 25% of compressed air.

4. Operating pressure reduction. In the distribution of compressed air in automated operations, the pressure maintained by the operator is often higher than optimal (it should be in the range of 0.4-0.6 MPa at workplaces, optimally up to 1.0 MPa in the distribution network of the production hall. Any necessary higher pressures need to be solved with a booster.

More and more often, in the recommendations of companies, you can meet savings in the way that significantly lower air pressure is used in the compressed air distribution network (on the order of 0.3-0.4 MPa) and it is increased on the power element by including a booster (pressure multiplier). However, it entails additional costs for purchasing the necessary amount of boosters. Without an assessment of costs and savings, one cannot agree with such a procedure.

5. Air leakage reduction. Losses of produced compressed air due to leaks in the distribution network of the operation and at the workplaces themselves often reach more than 20%. The average cost of preparing 1m3 of Class B compressed air (solid particles ≤0.3 μm, compressor oil content ≈1%, condensate ≈4%) is currently around €0.06 – €0.07.

The annual cost of producing compressed air at a working pressure of 0.6 MPa at this price and an operating time of 6,000 h/year and with a consumption of 20 m3/min of compressed air is approximately €500,000, of which 20% is €100,000.

6. Load reduction. It is not always possible to reduce the load on the working cylinders, but optimization is always in place.

7. Friction reduction. In this area, companies offering pneumatic drives have in their portfolio linear pneumatic drives with integrated sliding or rolling guides, which reduces the start-up of the mechanism's performance due to resistances in incorrect mass routing. Although these drives have a higher purchase price, the final savings combined with an extended service life are not negligible.

8. Selection of the right components. Components included in the pneumatic circuit should have their justification. For example, it makes no sense to add a microfilter or submicrofilter to the air conditioning unit intended for ordinary chip blowing in chip machining operations, which will necessarily reduce the flow through the main supply channel and thus cause a decrease in performance, which will necessarily lead to an increase in the value of the input pressure by the operator.

9. Open and closed loop control. It is necessary to train the operator in operation so that they use energy only as long as it is necessary. If, for example, it is enough to blow a turned part with compressed air for, say, 2 seconds, it is pointless to do so for 15 seconds. This is directly related to point 1, when by appropriate modification of the circuit using the ejector to generate a vacuum, we achieve a reduction in the time when the ejector is active and thereby save the air that would have to flow through it during the manipulation task, fig. 7.

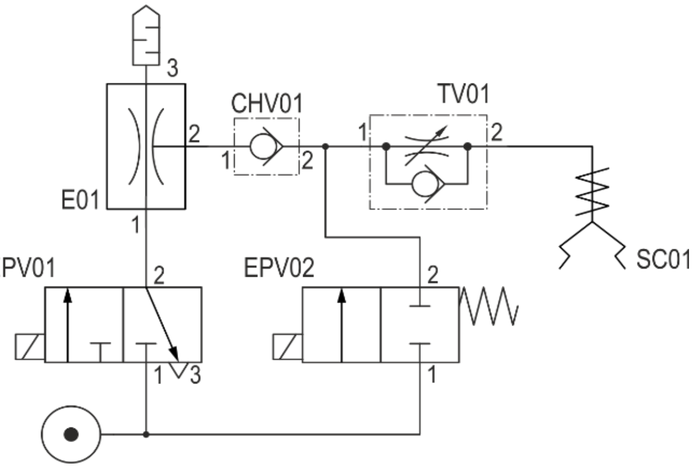

Fig. 6. Compressed air saving circuit arrangement for gripping with an active suction cup

10. Recovery of energy. Some solutions recommend "capturing" the used compressed air and re-compressing it with a lower energy load. However, the solution is quite demanding in terms of component equipment for such a modification.

11. Shutting down the power. This procedure is much more effective. It is possible to include a valve in air treatment units (FRL units), which disconnects the given workplace from the distribution network in operation at zero consumption.

12. Reduction of pressure drop. Just as it is not good for the optimal operation of the device to sharply reduce the flow channel, neither is the opposite procedure desirable. This mainly concerns the diameter of pipes and hoses and their reduction in workplace connection nodes. It is always necessary to look for the optimum depending on the needs.

Conclusions. The problem of saving compressed air, regardless of whether it is done for economic reasons or in the interest of improving the environment, will be a challenge to future generations for a long time to come. It is, therefore, appropriate to save energy of all kinds, because the vast majority of resources are exhaustible and carry a dangerous carbon footprint.

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ЗМЕНШЕННЯ ВУГЛЕЦЕВОГО СЛІДУ ПРИ ВИКОРИСТАННІ СТИСНЕНОГО ПОВІТРЯ В АВТОМАТИЗАЦІЇ

Під час проєктування та експлуатації поточних виробничих процесів все більше аналізується ступінь екологічного навантаження, пов'язаного з конкретною технологією. Це зазвичай називають вуглецевим слідом.

Оскільки автоматизоване виробництво значною мірою реалізується за допомогою стисненого повітря, доцільно поставити запитання, наскільки виробництво та використання цього середовища обтяжує наше середовище.

Якщо взяти до уваги той факт, що стиснене повітря виробляється в промисловому виробництві за допомогою компресорів, які працюють від електрики, вуглецевий слід, що виникає в результаті виробництва електроенергії, автоматично переноситься на вироблене стиснене повітря.

Під час енергоаудиту автоматизованої роботи зони економії стисненого повітря застосовуються відповідно до стандарту VDMA 24581 (Pneumatic fluid power - Application Notes for the optimization of energy efficiency of pneumatic systems) у виробництві та використанні стисненого повітря, де можна досягти дуже цікавих результатів за допомогою правильних рішень, що призводить до економії стисненого повітря.

У статті пропонується огляд і вказуються можливості вирішення проблем, що спричиняють марнотратне поводження з виробленим стисненим повітрям, наприклад, за допомогою інструментів, запропонованих у технічній практиці виробниками пневматичних компонентів.

Також представлено методику процедури проведення енергоаудиту та технічні засоби, які пропонують провідні виробники пневматичних компонентів.

Ефективність і коефіцієнт економії при використанні відповідних технічних засобів різна для різних територій, при цьому коливається в межах 10% - 60% економії.

Інформація, представлена у статті, є оглядовою.

Ключові слова: *стиснене повітря, енергоаудит, економія стисненого повітря, засоби моніторингу.*

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