ENERGY EFFICIENCY IN PNEUMATICS WITH THE “AIR SAVING BOX”: THE REVOLUTIONARY PLUG & PLAY SOLUTION FROM SMC

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ABSTRACT

For many companies, energy efficiency starts with production. For this reason, special consideration must be given to the production operation as a whole as well as its sub-areas. The strict legal requirements, as well as the companies' green policies which are defined as a result of these, create complex challenges, which SMC meets with expertise and passion as a manufacturer, partner and solution provider in electric and pneumatic automation technology. On the basis of an actual customer requirement, SMC Germany has developed an innovation in the field of pneumatic energy efficiency: “The Air Saving Circuit for double acting pneumatic cylinders”, under the working title of “Air Saving Box”. The underlying idea and focus of the solution was to make good use of the compressed air generated in existing cylinders, instead of simply allowing it to go to waste. The “Air Saving Box” enables significant energy savings in production. Based on this customised solution, SMC has also developed an industry-independent concept that can also be integrated into existing applications.

Keywords: Automation, energy efficiency, pneumatics, air saving, energy saving

1. INTRODUCTION AND PROBLEM DEFINITION

In 2015, a new agreement containing binding climate targets for all 195 member states of the UN Climate Convention was concluded in Paris as the successor to the Kyoto-Protocol. It was decided to limit global warming to less than 2°C in order to keep the effects of climate change within manageable limits. This requires a reduction in net greenhouse gas emissions. The intention therefore is to reduce net greenhouse gas emissions worldwide in the second half of this century [1].

Carbon dioxide (CO₂), the gas produced by the combustion reaction of carbon-containing materials such as wood or oil, makes up 72% of greenhouse gases emitted each year. The global concentration of CO₂ has increased by a good 44% since the beginning of industrialisation. In the 10,000 years before the Industrial Revolution, CO₂ concentration remained almost constant [2]. Despite strong economic growth, CO₂ emissions in Germany remained almost continuous at 800 million tonnes per year in the period from 2014 to 2017.

The German government's goal is to achieve a

reduction to 749 million tons by 2020 to meet the targets it has set itself under the Paris Climate Agreement [3].

In Europe, compressed air supply in the industrial and service sectors accounts for more than 80 TWh of electricity per year – that's around 10% of total industrial electricity consumption. Case studies have shown that possible savings potentials are not fully exploited due to opposing market and decision-making mechanisms [4].

SMC Germany offers energy saving audits as part of its service portfolio. Automation experts from SMC will examine a company's existing systems and offer individual advice on how it can reduce its compressed air consumption.

1.1. Practicability is a must

Experience from these audits has shown that, beyond the existing possibilities for saving compressed air, efficient solutions are needed in which cylinder force and cylinder speed remain unaffected, since the performance of existing machines must be available without any changes.

Figure 1: Schematic diagram of a bridge circuit consisting of four 2/2-way switching valves (left) and a short-circuited circuit (right).

SMC was set this objective by a customer who operates complex pneumatic systems in its production.

The initial starting point for the development was a detailed examination of the current state of technology and research.

2. STATE OF THE ART RESEARCH AND TECHNOLOGY

Preliminary investigations have shown that two switching methods are in principle particularly well suited for increasing the energy efficiency of pneumatic systems: a bridge circuit of four 2/2-way switching valves or a short-circuited circuit. These two circuits shown in **Figure 1** display an increased degree of functionality and a high compressed air savings potential in use [5]. Hence these two switching methods were first examined with regard to their practicability for installation in existing plants.

To implement a bridge circuit as shown in **Figure 1** a new control concept for the cylinder would have to be developed. This would require a deep intervention in the machine control system. When it comes to achieving an energy-, time- and cost-efficient compressed air reduction for existing plants, as required at the outset, this circuit is therefore only suitable to a very limited extent. A short-circuited circuit, on the other hand, would be easier and faster to integrate. This switching method was therefore pursued further.

2.1. Different saving potentials

Based on the chamber pressure curves of a double-acting piston rod cylinder with standard circuitry, the following compressed air saving possibilities were identified [5]:

- Chamber short circuit before switching the directional valve
- Chamber short circuit during the stroke
- Closing the compressed air supply during the stroke
- Closing the compressed air supply at the stroke end
- Exhaust air storage during the stroke
- Incomplete venting at stroke end
- Lower pressure level for required differential pressure
- Return stroke with reduced operating pressure

These eight possible operating methods were examined for their theoretical savings effects. At the same time, their practical feasibility for operators of existing plants with pneumatic components and systems was tested. Only practicable solutions that can be easily retrofitted were considered for the development of the individual customer solution.

A bidirectionally acting horizontal drive with a piston diameter of 32 mm, stroke of 100 mm, operating pressure of 7 bar, inner hose diameter of 4 mm and a length of 2 m [5] was considered, see **Figure 2**. Of the eight operating methods tested, six were rejected as unsuitable for the application. Although energy savings of up to 78%

Possible savings potentials		Savings potential
1 Chamber short circuit before switching the directional valve		18%
2 Chamber short circuit during the stroke		40%
3 Close compressed air supply during the stroke (use expansion energy)		78%
4 Close compressed air supply at stroke end		20%
5 Exhaust air storage during the stroke		47%
6 Prevent complete venting at stroke end		12%
7 Required differential pressure at lower pressure level		33%
8 Return stroke with reduced operating pressure		23%

Figure 2: Possible theoretical savings effects with exhaust throttled cylinders.

can be achieved, for example by shutting off the air supply during the stroke (method 3 in the picture), this always has a negative effect on cycle time, cylinder force or both. The same applies to methods 4 to 7, so they are not suitable for developing an energy-efficient and easily integrated solution that does not compromise on performance.

In contrast, methods 1 and 2 offer savings potentials of 18% and 40% with cylinder force and cycle time comparable to the initial state. For this, however, they require a specific control of the short-circuit valve. This represents too much interference with the control system for the specific application. The two methods were therefore considered to be only partially suitable.

2.2. New solution needed

Even if only standard components are used for the short-circuited circuit, a system operator cannot be expected to find the optimum operating point for the cylinder in the respective application. It is also unclear whether operators have the necessary

possibilities and knowledge to intervene in the machine control system in order to subsequently control a short-circuit valve.

Therefore, the two currently available short-circuit machine and plant manufacturers' entirely new designed system solutions. The specific application of a customer method are ultimately reserved for who wants to convert its existing machines in an energy-efficient way requires a completely newly developed technology.

3. OBJECTIVE

The new operating concept requires a solution that can be retrofitted to existing circuits, significantly reduces compressed air consumption and has no negative impact on force and cycle time. The solution should function independently so that it can be used with components from any manufacturer.

In addition, the innovation should be as industry-independent as possible, to ensure that it can be used beyond the individual application and thus help as many operators of pneumatic systems as possible to save energy.

4. PROCEDURE

On the basis of the short-circuited circuit, tests are being carried out to determine whether a pneumatically controlled variant can be implemented that takes account of the pressure conditions on both sides of the cylinder chamber and thus achieves the optimum energy-saving effect with practically no additional control. All basic load cases are considered in addition:

- horizontally operating, double-acting cylinder

- double-acting cylinder working vertically upwards against the load
- double-acting cylinder working vertically downwards with the load

The values for piston diameter, stroke and load are varied during the experiment.

4.1. Real application

A real application with classic circuitry of a double-acting cylinder via 5/2-way valve serves as a reference and starting point for the development. In the reference application, a speed controller is not used to achieve a shorter cycle time and thus higher machine speed, see **Figure 3 left**.

The classic circuit was compared with the newly developed short-circuited circuit by SMC using the “Air Saving Box”, **Figure 3 right**.

Figure 3: Classic control of a bidirectional cylinder with 5/2-way valve (left) and compressed air-saving control based on the short-circuited circuit with the “Air Saving Box” (right).

The respective pressure curves in the cylinder chambers are measured as well as the compressed air consumption, which was documented before the valves with the help of a flow sensor. The respective results are put in relation to each other according to the following formula:

$$E [\%] = \frac{V_{\text{classic}} - V_{\text{Air Saving Box}}}{V_{\text{classic}}} \quad (1)$$

5. CURRENT STATUS

The performance of cylinders with the “Air Saving Box” must not be less for the customer application than that of a conventionally switched cylinder. SMC therefore measured the energy efficiency, cylinder force and stroke time under various parameters, such as cylinder diameter, cylinder stroke, hose volume and installation direction of the cylinder without and with load. The “Air Saving Box” is mounted on the piston rod side cylinder chamber. It therefore acts in the extension stroke and reduces the compressed air consumption without further control measures, (see **Figure 4**) making it easy to integrate into existing systems.

Figure 4: Comparative display of the required compressed air flow rate of a classically controlled bidirectional cylinder (dark) and a cylinder controlled to save compressed air with the “Air Saving Box” (light). Good to see: the significantly reduced flow rate in the extension direction.

As **Figure 4** shows, the short-circuited circuit with the “Air Saving Box” in the extension direction significantly reduces the required compressed air flow. This value and the associated reduction in compressed air consumption as an area under the compressed air flow serves as a measure of the energy saving and energy efficiency of the application. In laboratory tests, savings of up to 50% have been achieved with this formation. In the retraction direction, however, the compressed air flow – and thus the compressed air consumption remains unchanged.

5.1. Positioning and load mounting

Further laboratory tests have confirmed that the compressed air savings depend largely on the installation direction and the mounted load. For example, a vertical set-up in the laboratory showed that the statically applied positioning energy of the moving load can be converted into compressed air savings. Furthermore, the hose length and the hose volume have a significant influence on the cylinder speed.

The next step is to further develop the solution for cross-industry use. For this purpose, the parameter influences are determined in the laboratory under scientific aspects. This allows the characteristic map data for the use of the “Air Saving Box” to be worked out. SMC also focuses on customer applications in order to be able to define the application parameters as realistically as possible.

6. CONCLUSION AND OUTLOOK

On the basis of an actual customer requirement, SMC Germany has developed an innovation in the field of pneumatic energy efficiency: “The Air Saving Circuit for double acting pneumatic cylinders”, or “Air Saving Box” for short. The focus was on making good use of the compressed air generated in existing cylinders, instead of allowing it to go to “waste”, and use “fresh” compressed air.

SMC’s “Air Saving Box” creates significant energy savings in production. Based on the knowledge gained from the development process of this initially individual customer solution in Germany, SMC is now developing a product for worldwide use that is industry-independent and can be integrated into all applications.

Current societal and industrial efforts suggest that plant operators are opening up to energy-efficient solutions that involve the lowest possible investment costs and operating risks.

The “Air Saving Box” optimally meets these requirements and will considerably increase the efficiency of pneumatics in a wide range of applications. SMC is thus contributing to the goals of our federal government to drastically reduce CO₂ emissions and to reduce overall net greenhouse gas emissions to zero in the foreseeable future.

NOMENCLATURE

E	Savings
$V_{classic}$	Compressed air consumption (classic)
$V_{Air\ Saving\ Box}$	Compressed air consumption (with “Air Saving Box”)

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