FACTA UNIVERSITATIS
Series: **Mechanical Engineering** Vol. 9, N° 2, 2011, pp. 161 - 168

INFLUENCE OF PISTON ROD CLAMPING UNIT ON INCREASED ENERGY EFFICIENCY OF COMPRESSED AIR SYSTEMS

UDC 621.542

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Abstract. *Requirements for increased energy efficiency and lower energy consumption, i.e., efficient and rational exploitation of energy resources, are today the global imperative which has been a subject of international treaties and standards. Bearing in mind that the compressed air is one of most widely used energy carriers in industry as well as the subject of aforementioned requirements, this paper is a contribution to investigations on the increase of energy efficiency of compressed air systems by reducing unnecessary consumption. In view of this objective, the paper analyzes the effects of the piston rod clamping unit application and its influence on energy efficiency of compressed air systems.*

Key words: *Energy Efficiency, Compressed Air, Clamping Unit*

1. INTRODUCTION

After electrical energy, compressed air is the second most frequently used in industry [1]. The compressed air systems are also used in many other areas of human activity. They are especially popular in the sectors which prioritize occupational safety and environment protection.

Compressed air is increasingly gaining popularity in industry thanks to its operating velocity, explosion and environment safety, overload safety, easy regulation of speed and force, reliability of components and operational longevity. It is used in various manufacturing applications, as well as for driving pneumatic tools, cleaning work areas, pneumatic transport, etc.

Majority of these applications are energy inefficient which is one of the main reasons why air compressors in industry plants represent significant energy consumers. Compressed air is also an expensive energy carrier. An average structure of costs for the compressed air

Received May 11, 2011

production within a lifecycle is shown in Fig. 1. It is obvious that most of the compressed air production costs are attributed to electrical energy, investments, and maintenance.

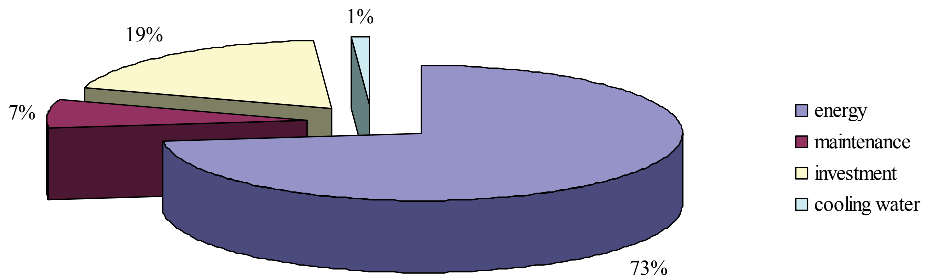


Fig. 1 The most significant costs of compressed air production

The significance of these costs is reflected in the fact that approximately 10 % of EU electricity is spent on compressed air production [2], while in Serbia that number is around 8% [3].

Many production systems efficiently use just a fraction of the total compressed air production, so the necessity for system optimization and development of measures for their efficient use of energy becomes obvious.

The increase of energy efficiency of the compressed air systems can:

- save energy,
- reduce maintenance and break-downs,
- increase productivity of entire system, and,
- improve compressed air quality.

Besides the economic effect, the increased energy efficiency of the compressed air systems is also important from the ecological and environment protection aspects. The reduction of the unnecessary compressed air losses is reflected in lower production of compressed air, which, in its turn, decreases the emission of CO_2 and other harmful matters into the atmosphere.

2 Energy Efficiency of Compressed Air Systems

Energy losses occur in various parts of the compressed air system, from the compressed air production to its distribution and consumption.

The heat losses generated during the air compression represent the most significant losses in the process of compresses air production. Although only 6% of the electrical energy consumed by the system cannot be regenerated, most of the energy is still irreversibly lost to heat emission from the system. Besides the thermal emission, the structure and volume of losses in the process of compressed air production are also influenced by:

- location and installation of compressor,
- compressor drive,
- compressor maintenance,
- lubrication,
- selection of compressor, and,
- compressor control system.

On the other side, the major losses in the process of the compressed air distribution are attributed to leakage. Such losses usually constitute 25-30 % of the total compressed air consumption, while in some systems they can even go as high as up to 50 % [4]. While being one of the most important sources of compressed air losses, leakage is most easily managed, i.e., minimized in order to reduce losses. In the typical, well managed plants, leakages take up 2 to 10 % of the total compressed air consumption.

The compressed air systems hold significant potentials for energy saving. Energy savings can be achieved by:

- applying energy efficient drive motors,
- adequate preparation,
- heat regeneration,
- adequate selection of work pressure,
- reduction of compressed air leakage from installations,
- leveling out of compressed air consumption,
- selection of adequate system control,
- proper maintenance, etc.

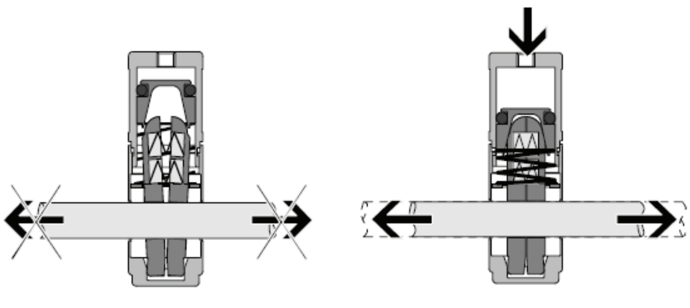
The most simple and efficient way of increasing energy efficiency of the compressed air systems is the reduction of unnecessary losses. The reduction of total losses in the compressed air system can be achieved by one of the following methods:

- reduction of losses due to compressed air leakage,
- reduction of consumption of particular pneumatic components in the system [5],
- reduction of friction, and,
- reduction of pressure losses in the system.

Considering this, special attention is paid in this paper to the piston rod clamping unit, as one of the factors which may contribute to reduction of the superfluous compressed air production due to a leakage in the pneumatic operating components.

3 Increase of Energy Efficiency through Application of Piston Rod Clamping Unit

The clamping cartridge in the clamping unit or in the cylinder with clamping unit holds the piston rod firmly in any position. When the clamping cartridge is exhausted, a spring presses the clamping jaws apart (Fig. 2a). As a result the jaws are tilted on the piston rod and it is clamped.



a) without pressurization (frictional connection) b) with pressurization (free clamping rod)

Fig. 2 Clamping cartridge placed on piston rod

When the clamping cartridge is pressurized through the compressed air connection from the upper side (Fig. 2b), the piston presses the clamping jaws together until the jaws are parallel to each other. The holes in the clamping jaws then lie in an axis with the clamping rod. The clamping is loosened and the piston rod can move freely.

The clamping unit is intended for the following applications:

- Holding or clamping round material or the piston rod in any desired position
- Avoiding stroke movements due to:
  - fluctuations in the operating pressure,
  - leakage on seals or tubing.

The basic advantage of the piston rod clamping unit is the fact that it allows for an interruption of the compressed air supply by preventing the stroke movement of the piston rod in a specific position.

The drawback of this solution is the increased length of the piston rod due to larger overall piston dimensions, as well as the requirement for an additional fixture for clamping unit air supply, which increases the possibility of a leakage.

Besides preventing stroke movements due to compressed air leakage, the clamping unit may contribute to an increase of energy efficiency. The goal of this research is to establish the influence of the piston rod clamping unit on the reduction of losses due to the compressed air leakage in seals and hoses, which can ultimately lead to higher energy efficiency.

3.1 Case Study

The difference in the compressed air consumption in the case of using a standard double acting cylinder and a cylinder with piston rod clamp unit, is experimentally established as described in the following case study.

During a typical work cycle of the double acting cylinder, the piston rod remains extended for a two minute interval, after which it retracts to its initial position. In the first case, the cylinder is constantly supplied with compressed air, while in the second case, instead of a 5/2 distributor, a 5/3 distributor with mid-position blocking is used; and once the piston rod is extracted, the clamping unit gets engaged in cutting off the air supply. In this case study the electro-pneumatic control is used. The control diagram with the piston rod clamping unit is shown in Fig. 3.

Measurement of the compressed air consumption is performed by the Festo Air box portable lab. The location of experiments and part of equipment used in experiments is shown in Fig. 4.

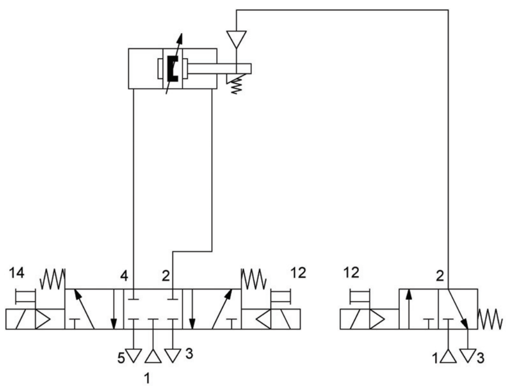


Fig. 3 The control scheme with clamping module

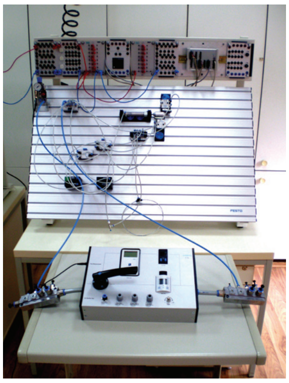


Fig. 4 The experimental facility

Fig. 5 shows the diagram of compressed air supply for the cylinder equipped with piston rod clamping unit under regular exploitation conditions

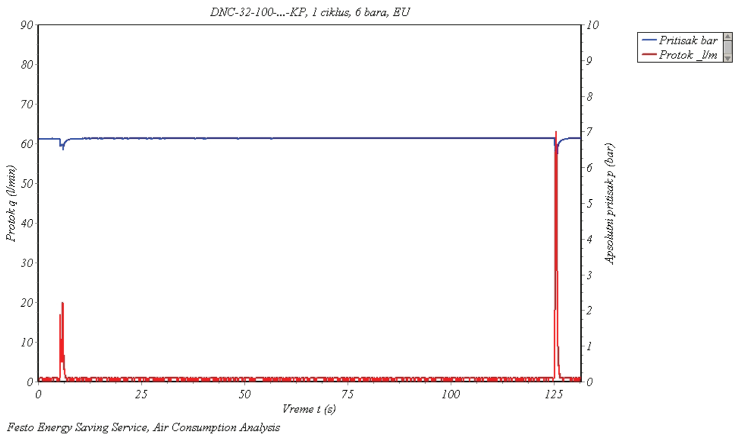


Fig. 5 Diagram of consumption of compressed air pneumatic cylinder with clamping module for cylinder DNC-32-100-...-KP in one working cycle

Analysis of the diagram and integration of surface under the compressed air flow curve yields compressed air consumption of 0,69 l within a single work cycle.

In the second case, the influence of piston rod clamping unit on system energy efficiency is considered in the case of a significant compressed air leakage in the pneumatic cylinder, which is most often due to faulty pneumatic connectors and seal rings.

Shown in Figs. 6 and 7 are the diagrams of the compressed air consumption in the case of a damaged piston rod seal ring which causes leakage for a standard double action cylinder and a double action cylinder with the piston rod clamping unit.

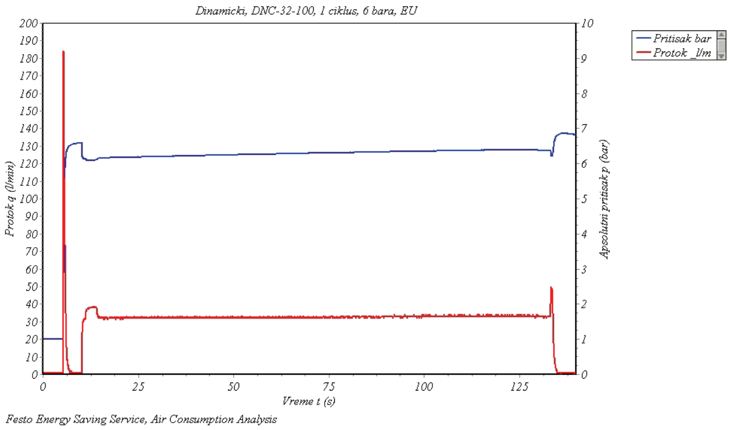


Fig. 6 Diagram of consumption of compressed air standard pneumatic cylinder DNC-32-100 with a damaged seal piston rods in one working cycle

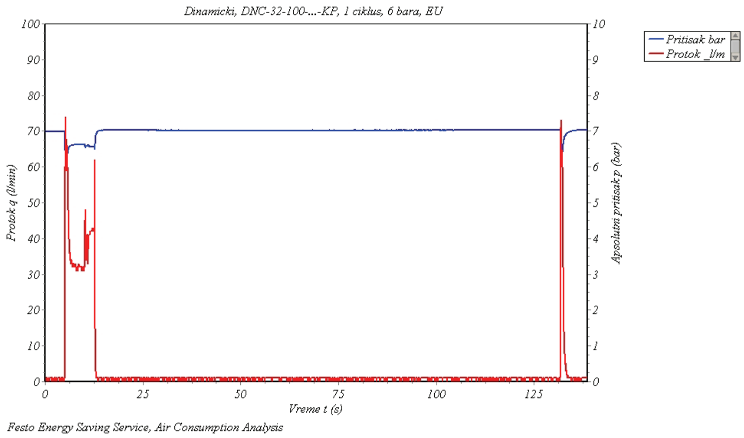


Fig. 7 Diagram of consumption of compressed air pneumatic cylinder with clamping module DNC-32-100-...-KP and the damaged seal piston rods in one working cycle

Analysis of the diagram and integration of surface under the compressed air flow curve yields compressed air consumption shown in Table 1.

Table 1 Comparative overview consumption of compressed air in case of leakage

Consumption	Consumption Q (l/cycle)
double acting cylinder DNC-32-100	69,29
cylinder with piston rod clamp unit DNC-32-100-...-KP	5,81

The difference of 63,48 l in compressed air consumptions shows that a reduction of 91,64 % of compressed air is achieved per work cycle in the case when clamping unit is applied.

Effects of application of the piston rod clamping unit in both cases are shown in Table 2.

Table 2 Effects of clamping module application in both case

price of a m^3 compressed air	0,020 €/m^3
effective capacity	180.000 min/year
during one cycle	2 min
number of cycles in a year	90.000 cycle/year
savings of air	63,47 l/cycle
additional investment costs	280 €
savings of money	114,24 €/year
payback period of investment	2,4 years

From Tab. 3 is evident that, in the case of leakage, the compressed air savings amount to 114 €/year, while the payback period for the required investment is 2,5 year. This renders the discussed solution highly cost-effective.

4 Conclusions

The analysis of the results obtained in this investigation leads to the conclusion that the piston rod clamping unit application has a little effect on energy efficiency of the compressed air system in the cases with none or insignificant air leakage.

However, in the cases of some significant compressed air leakage, which often happens, the piston rod clamping unit application leads to a significant increase in system energy efficiency. The payback period for the necessary investment is very short due to compressed air savings, and in this example it amounts to just 2,4 years. The clamping unit application is especially important in the cases of high compressed air consumption with large diameter cylinders, which, due to the exploitation regime, cannot be replaced when needed, i.e., in the cases of a significant compressed air leakage.

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UTICAJ PRIMENE MODULA ZA BLOKIRANJE POLOŽAJA KLIPNJAČE CILINDRA NA POVEĆANJE ENERGETSKE EFIKASNOSTI SISTEMA VAZDUHA POD PRITISKOM

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Povećanje energetske efikasnosti i potreba da se smanji potrošnja energije u svetu, odnosno da se efikasno i racionalno koriste energetski izvori, danas predstavlja obavezu koja je postala globalno pitanje i predmet međunarodnih sporazuma i standarda. Imajući u vidu da je vazduh pod pritiskom jedan od najrasprostranjenijih prenosnika energije u industriji, i da je pod istom obavezom, ovaj rad predstavlja doprinos istraživanjima mogućnosti povećanja energetske efikasnosti sistema vazduha pod pritiskom smanjenjem neprimerene potrošnje vazduha. U tom cilju, u radu se analiziraju efekti primene modula za blokiranje klipnjače cilindra i njihov uticaj na energetsku efikasnost sistema vazduha pod pritiskom.

Ključne reči: *energetska efikasnost, vazduh pod pritiskom, modul za blokiranje položaja klipnjače cilindra*