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INCREASING ENERGY EFFICIENCY OF COMPRESSED AIR USAGE FOR SUSTAINABLE PRODUCTION OF FOOD AND BEVERAGE

ABSTRACT:
In order to achieve sustainable production, many efforts are invested in efficient production. Significant part of these efforts is made in the field of increasing energy efficiency. Particularly, in this paper attention is paid to increasing energy efficiency in pneumatic systems. Certain investigation and improvements are done in one beverage company in Serbia. In this paper is given an investigation of packaging and pallet machines, which had an inefficient work regime, inappropriately defined pressure, and position of suction cups. After investigation and applied corrections, significant results are obtained in the field of energy efficiency and sustainable production.

KEYWORDS:
energy efficiency, sustainable production, food and beverage industry, compressed air

INTRODUCTION

In order to meet the sustainability challenge, industry must include not only the eco-efficiency but also the product's environmental justification and the company policy in a production in order to become sustainable. Achieving sustainable development will require changes in industrial processes, in the type and quantity of resources used, in the treatment of waste, in the control of emissions, and in the products produced.

Using as an example one of the biggest beverage company in Serbia, this paper examines problem related to the efficient use of compressed air in the production. Results indicate that it is possible to identify and improve some points in the production process, in order to increase energy efficiency in the manner of sustainable production. An examination of the two machines into the company provides useful ideas and enables the quantification of saving which could be achieved by applying them. In this paper are presented the main problems on the packaging and pallet machine, some procedures for the improvements are suggested and applied, and, finally, achieved effects are measured and described. Among other facilities, energy consumption has significant impact on sustainable production. This paper describes examples how different factors, such as poor maintenance, inappropriate working regimes and usage of inadequate or less energy efficient components and devices, affect on increased compressed air consumption. These examples are described with real case studies from companies.

PROBLEM DESCRIPTION

One of the biggest beverage factories in Serbia had huge problems with packaging and pallet machines. They had big loses of compressed air, maintenance operations were very frequent and, the most important, they had breakdowns in the production.

After the thorough energy efficiency audit [1], several critical spots are marked, where obvious problems with compressed air were present. Two machines are selected for detailed analysis.

The first one was the machine for inserting glass bottles into the plastic crates [2], so-called packaging machine. The operators on the machine noticed that there are significant pressure drops during the machine operation. In some cases, that led even to the dropping and breaking the glass bottles. This machine has three carriers. One carrier has four rows with seven heads, each head for handling a single bottle. Each row has its own air supply, Figure 1. Each carrier inserts 4 x 7 = 28 glass bottles into the crate, in one cycle.

The main problem was with the rubber, which is placed into the head. During the operation, rubbers are wearing out and causing air leaks. Therefore, it is necessary to change the damaged rubber, what has often been neglected. The problem was in absence of every day inspection of the machine and poorly organised preventive maintenance.

The second problem was related to the pallet machine [3]. The part of this machine, the vacuum gripper, picks paperboard from the stock and places it on the pallet.

One pallet has five paperboards, between each level. Each level of pallet contains packages of the plastic bottles, Figure 2. Vacuum griper has four suction cups, Figure 3, and vacuum is generating on the Venturi principle.

Figure 1 - Head arrangement with the air supply in the carrier

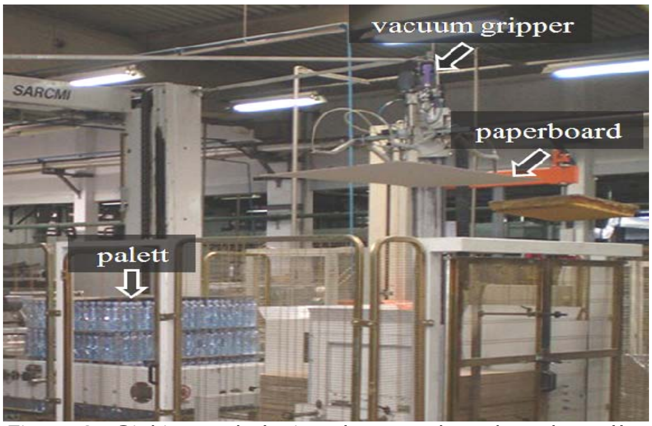


Figure 2 - Picking and placing the paperboard on the pallet

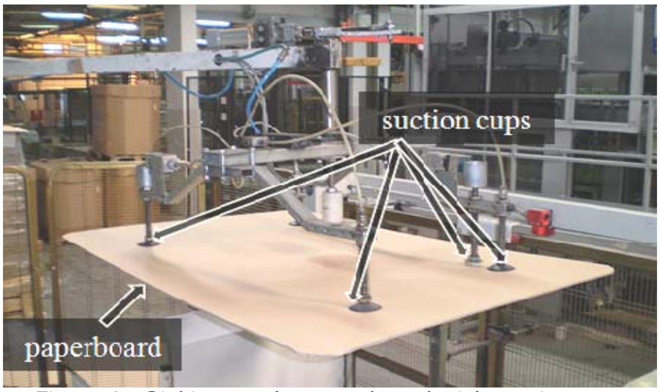


Figure 3 - Picking up the paperboard with suction cups

This machine had energy inefficient work regime and inappropriate usages of compressed air were huge. Besides good maintenance practice, losses were significant. The reason for that is unsuitable determined and set up work regime.

MEASUREMENTS AND METHODOLOGY

Firstly, measurements were conducted on the packaging machine, using the AirBox device, from the manufacturer FESTO.

The device was connected to the air supply of the first row of heads in the first carrier. This row was chosen because there was only one faulty head there. Air consumption was measured in static mode (machine is off), but air supply was enabled. Comparing that result with the air consumption of the faultless row, it was easy to determine loses of compressed air on the single head.

There were two faulty head on average in each row. Hence, it was simple to calculate the annual volume of compressed air that is lost on the packaging machine.

After the measurement, acquired results are presented in Table 1 and Figure 4, a.

Table 1 - Part of the obtained results about air consumption

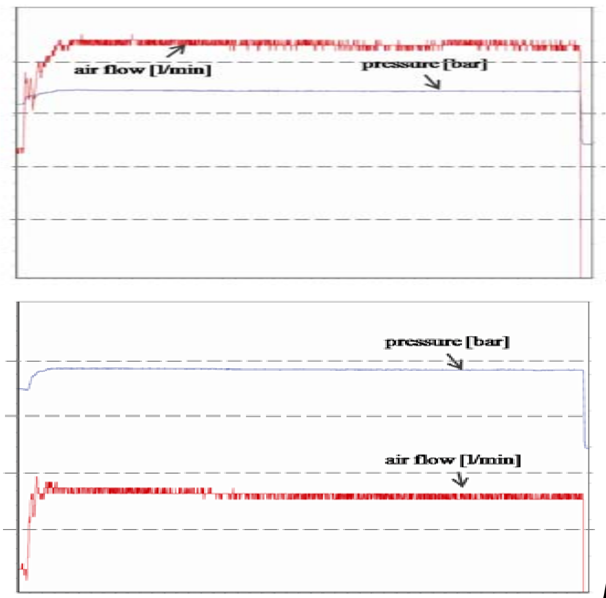
No.	air flow Q [l/min]	pressure p [bar]	interval between two measurements-Δt
1	49,6	1,06	0,049805
2	89,7	1,06	0,049805
3	95	1,19	0,049805
:	:	:	:
2427	107,6	1,38	0,049805
2428	107,6	1,38	0,049805
2429	72,8	1,31	0,049805
n = 2429	$\sum_{i=1}^{n} Q_i = 259759$		

Using the equation:

$$\overline{Q_i} = \frac{\sum_{i=1}^{n} Q_i}{n}\left[\frac{l}{\min}\right] = \frac{259759}{2429} = 106,94\ \frac{l}{\min}$$

it was calculated the average volume of leakage on the one failed head, which amounts 107 l/min.

After the measurement, the bad head was replaced with the new one. After that, measurement was repeated and the better results are obtained, Figure 4, b. Air flow, after the corrections, was 80 l/min. Reduction of air leaks amounts to 27 l/min, which can be noticed on the diagrams, also.



a)

b)

Figure 4 - Obtained air flow on the first row of head: a) before, b) after replacing the head

The second measurement was carried out on the pallet machine, and it is determined that vacuum griper consumes 315 l/min of compressed air. From the energy efficiency point of view, that is huge volume of compressed air for this type of applications.

Big problem with this vacuum gripper is in its work regime. Immediately, after placing one paperboard on the pallet, it picks up the next one and holds it in the upper position until the new row of bottle packages is placed on the pallet. That period lasts 20-30 s, in average. During that time, vacuum is generating constantly. In some unpredictable situations of malfunctions in the line for forming bottle packages, the upper position of vacuum gripper with the paperboard, might last dozens of minutes, or even several hours in the cases of big accidents. Over that time, compressed air is spending for generating vacuum. This is an inefficient way for consuming the compressed air and the costs increase rapidly.

Recommended procedure for optimising the vacuum griper encompasses three steps:

1. Improvement of the work regime with reprogramming the controller, which regulates vacuum gripper.

Vacuum gripper should be reprogrammed in the way that, after placing the last of package bottles on the pallet, it picks up the paperboard from the stock. Current time of 20-30 s would be reduced to 5-6 s for consuming compressed air for generating the vacuum.

2. Replacement of the vacuum generator with the new, efficient one, with integrated air saving circuit.

Vacuum generator with air saving circuit generates the vacuum up to defined level and after that switches of. When the vacuum level falls below the required range, vacuum generation is activated automatically, Figure 5. The main point of this type of vacuum generator is that it does not generate vacuum constantly. There is a tolerance range within the vacuum level. When the vacuum level falls down below the level necessary for picking and placing the paperboard, vacuum starts generating again [4].

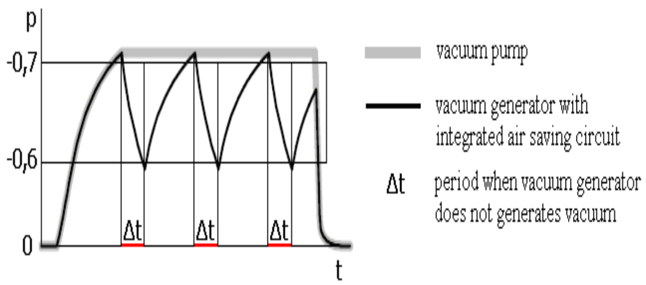


Figure 5 - Working principle of the vacuum generator with integrated air saving circuit

Implementing the vacuum generator with integrated air saving circuit, air consumption would be reduced from 315 l/min to 50 l/min.

3. Reducing the pressure level.

Diagram of the compressed air consumption for generating vacuum, and diagram of vacuum level, for the vacuum generator with integrated air saving circuit, is presented in the figures 6 and 7, respectively.

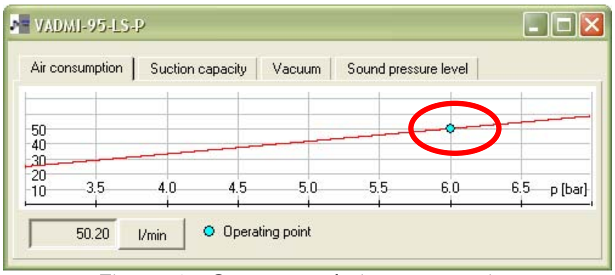


Figure 6 - Compressed air consumption at pressure level 6 bar

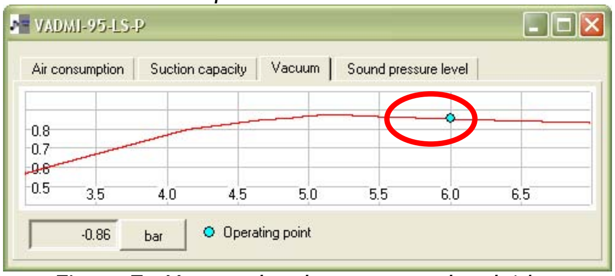


Figure 7 - Vacuum level at pressure level 6 bar

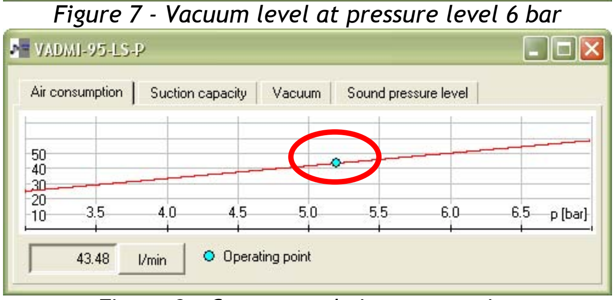


Figure 8 - Compressed air consumption at pressure level 5,2 bar

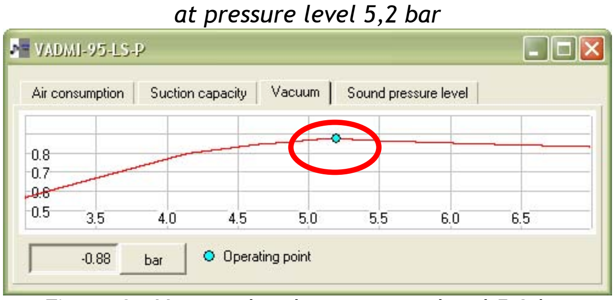


Figure 9 - Vacuum level at pressure level 5,2 bar

As it can be noticed from the figure 7, the highest level of vacuum is at 5,2 bar. If we reduce the initial pressure level of 6 bar to 5,2 bar, savings of 6,7 l/min can be achieved, figures 8 and 9.

DISCUSSION

Packaging and palletising machines can save significant volume of compressed air with relatively small investments and better maintenance procedures.

Packaging machine has two failed heads in each row, in average, which is eight head on one carrier, or twenty-four head on the whole machine.

Total time of working cycle, which encompasses time needed for inserting bottles into the crate, is 12 seconds. Compressed air is consumed 5,2 s of that period, and the rest of the time is spent for setting the heads into the position for picking up the bottles. In the other words, compressed air is spent during 45% of working time of packaging machine.

Packaging machine manipulates with the average of 75 600 000 bottles annually. If we consider that the packaging machine places 7 (heads) x 4 (rows) x 3 (carriers) = 84 bottles in one cycle, there are 900 000 cycles per annum.

We have already determined that there are two faulty heads, in average, in each row on the carrier. During the measurement, the air leakage on the one failing head was 27 l/min, Figure 4, or 2 x 27 = 54 l in one row. In just one cycle, that amounts to 54 x 0,45 =24,3 l/row. There are 12 rows on the machine and the total leakage amounts to 24,3 x 12 = 290 l of compressed air in one cycle.

If we take into consideration 900 000 cycles per year, we get 290 x 900 000 = 261 000 m^3 of compressed air. Production costs for one cubic meter of compressed air take € 0,12. That means that annually savings are € 4 000, with maintenance costs, which are relatively minor.

Situation on the pallet machine is little complicated because of three proposed steps of improvements.

In the condition without breakdowns and malfunctions, one cycle of palletizing lasts 2,38 min = 158 s, in average. Vacuum generator operates 136 s, Figure 10. During the one cycle, vacuum gripper places five paperboards onto one pallet, and it operates 86% times of the cycle. There are 23 cycles within one hour, or 69 000 cycles in one year.

Annual consumption of compressed air on the vacuum griper amounts:

$$69000\frac{cycles}{year}\times 125\frac{s}{cycle}=143750\frac{\min}{year}\rightarrow$$

$$143750\frac{\min}{year}\times 315\frac{l}{\min}\approx 45280\frac{m^3}{year}.$$

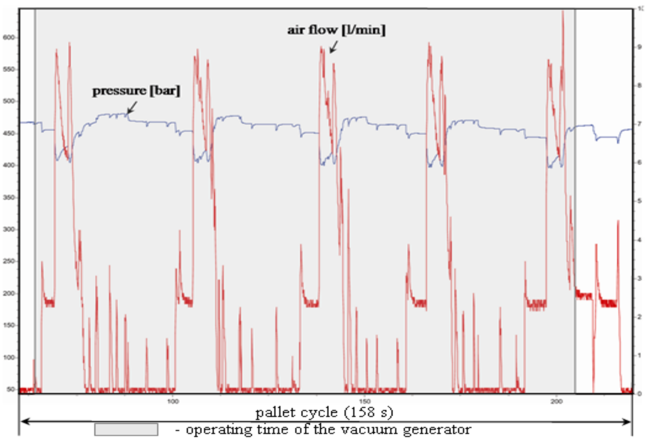


Figure 10 - Consumption of compressed air on the pallet machine in the one cycle

By the reprogramming the controller which regulates the functioning of the vacuum generator, in a way that after placing the last package of bottles on the pallet it picks up the paperboard from the stock, operating time of the vacuum generator would be reduced from average 20 to average of 5 seconds. Air consumption in that case would be:

$$69000\frac{cycles}{year}\times 25\frac{s}{cycle}=28750\frac{\min}{year}\rightarrow$$

$$28750\frac{\min}{year}\times 315\frac{l}{\min}\approx 9056\frac{m^3}{year}.$$

Volume of consumed air per year would be decreased by 45 280 - 9 056 = 36 220 m^3, or 80%. With the calculation of price of compressed air, annual savings, with just this simple reprogramming, would amount to € 550.

Savings would be more significant and apparent in cases of accidents, when appears sudden stoppages. In that cases compressed air would be not used for generating vacuum, like it happens now. Vacuum generator would not be in the operation until the last package of bottles comes on the appropriate pallet level.

With the replacement of the current vacuum generator with the energy efficient one (with integrated air saving circuit), air consumption would decrease from current 315 l/min to 50 l/min (Figure 6). With the average working time of the vacuum generator per year and 69 000 cycles per year, additional savings would be achieved:

$$28750\frac{\min}{year}\times 50\frac{l}{\min}=1437\frac{m^3}{year}$$

of compressed air, or savings of 85%. If we calculate production price of compressed air, € 115 would be saved just on one vacuum generator. Vacuum generator with integrated air saving function costs approximately € 350. Return of investment would be less than three years, but significant saving would be achieved on compressing of air. (2)

Reduction of the working pressure for the vacuum generating by 0,8 bar (from 6 to 5,2 bar), would lead to the reduction in compressed air consumption, from 50 l/min to 43 l/min (figures 6 and 8). In this particular case, this reduction does not bring significant savings. However, our intention was to call attention to this kind of possible actions for increasing energy efficiency and sustainable production.

CONCLUSION

Consumption of compressed air is wide spread, but, at the same time, it does not get enough attention in production companies. Therefore, it is often used in an inappropriate manner. Companies with an increased awareness for environmental protection and the need of sustainable production processes, continuously increase energy efficiency of compressed air systems. In this paper is given a very good example about how significant savings can be achieved with the minimum of investments and other additional costs.

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