Compressed Air Savings During Cooling and Cleaning of Product

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Abstract. The paper deals with possibilities of reduction of compressed air consumption during cooling of drill bit and pressure cleaning of products. First part is focused on the experimental verification of the air consumption of the production machine. On the basis of the experiment in second part of paper the modifications of machine which are aimed to reduction of air consumption are proposed.

1 Introduction

Compressed air is used not only to drive of pneumatic mechanisms but also in some applications for cooling or cleaning products or tools. In these cases, often simple solution is used - the air flow from tubes or hoses. The amount of flowing air can be controlled by a throttle valve. This solution, see Figure 1, is structurally simple, the production costs are low but in operation it shows low efficiency and unnecessary waste of the compressed air.

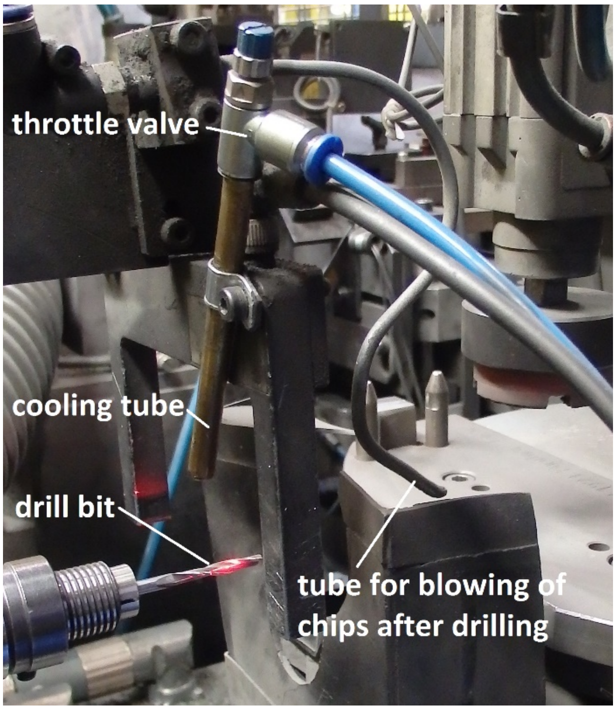

Fig. 1. Photo of drilling part of the product machine

Based on the industry demand, we have dealt with the possibilities of air savings on production machines [1]. As a part of our research, we first measured air consumption when drilling holes on two machines - the production (assembly) machine and the CNC drill. In a second phase, we proposed the device modifications and on the base of it we quantified possible savings of the compressed air. Consumption measurement was performed such that the flow meter has been included in the inlet tube for cooling and blowing of chips. At the same time, the pressure at the inlet to the tube was measured. Based on the measurements, the operating costs were calculated. In the calculation we used the price of the compressed air $0{,}5\ CZK/m^3\ (ANR)$ (Atmospheric Normal Reference). The results are in Table 1.

Table 1. Consumption of compressed air and its cost

quantity	assembly machine		CNC drill
	cooling	chips blowing	chips blowing
flow rate $[dm^3 \cdot min^{-1}\ (ANR)]$	52.7	130	71.5
inlet pressure $[MPa]$	0.65	0.63	0.68
total consumption per 1 hour $[m^3\ (ANR)]$	3.162	7.800	4.29
compressed air cost per 1 hour $[CZK]$	1.58	3.9	2.15
compressed air cost per 1 year* $[CZK]$	6570	16220	8945

*260 working days, two-shift operation (16 hours)

At this point, it should be noted that the air has been flowing out all the time since the machine was switched on until it was switched off. Air was wasted outside of production time, for example during breaks, when the tools was replacing, etc. This, of course, greatly increases total costs. Modifications and possible savings will be further described on the example of the drill bit cooling.

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In this case, the year-round operation cost is about 6570 CZK.

2 Proposed modifications of the machine

In this case, there are two ways to reduce air consumption. The first is to use the amplifier (high efficiency nozzle) instead of the tube. The second possibility is to switch on cooling only when it is needed. Of course, it would be possible to combine both ways. These options are compared below.

2.1 High efficiency nozzle

Producers of pneumatic components offer a number of components for blowing, cleaning and cooling products or working tools. These elements include various types of nozzles and so-called air knives.

Due to the optimised shape, the air knife provide slim output of air flow with high power and speed, Figure 2.

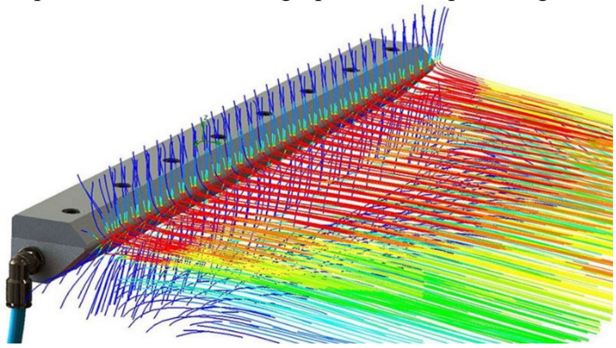

Fig. 2. Air flow from air knife [2]

Unique knife shape causes suction of surrounding air which increase the total capacity of air flow.

Another possibility is to use some kind of nozzle. For cooling applications, an amplifier nozzle or high efficiency nozzle is suitable. Like the air knives, these nozzles also suck surrounding air as shown in Figure 3 and Figure 4.

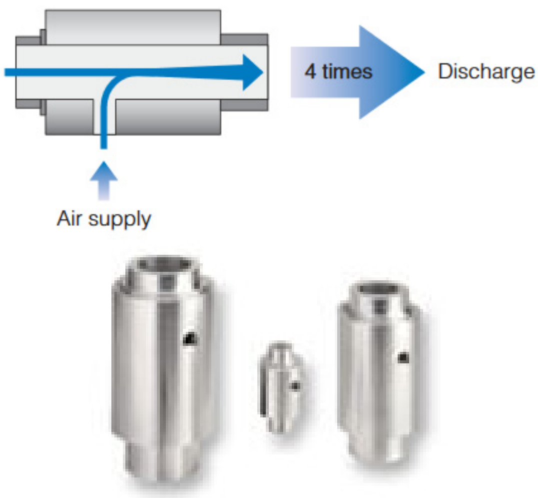

Fig. 3. Air amplifier [3]

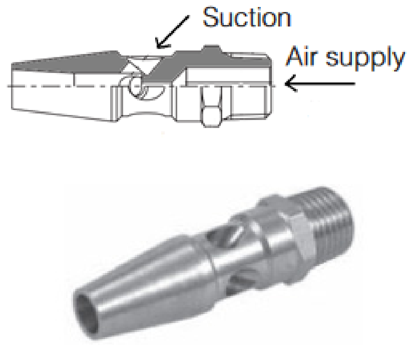

Fig. 4. High efficiency nozzle [4]

Due to the minimal requirements for modifications the machine design, the highly efficient nozzle type KNH-R02-150 from SMC was chosen. The nozzle has a diameter of $1.5\,mm$. At a maximum inlet pressure of 1 MPa the air consumption is $200\ dm^3 \cdot min^{-1}\ (ANR)$.

To compare cooling efficiency with a 3.8 mm diameter tube and a nozzle, a simple experiment was performed. Using a Prandtl tube, the velocity profile was measured from the axis of the air flow to its edge, see Figure 5. The velocity profile was measured at a distance of $35\,mm$ from the end of the tube. This distance corresponds to the actual conditions on the machine. The same pressure and flow rate as on the machine were set using the pressure regulator and throttle valve. Measurements were first carried out at an inlet flow rate (air consumption) of $52\ dm^3 \cdot min^{-1}\ (ANR)$.

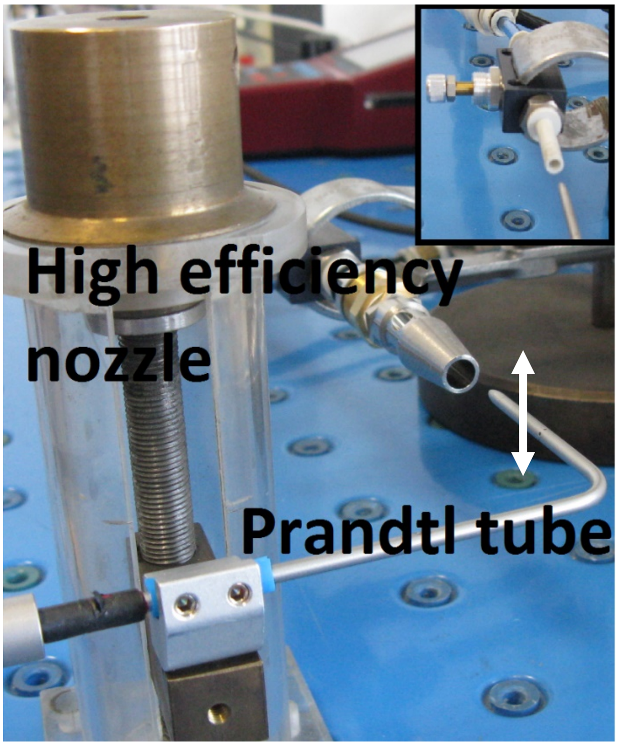

Fig. 5. Measurement device

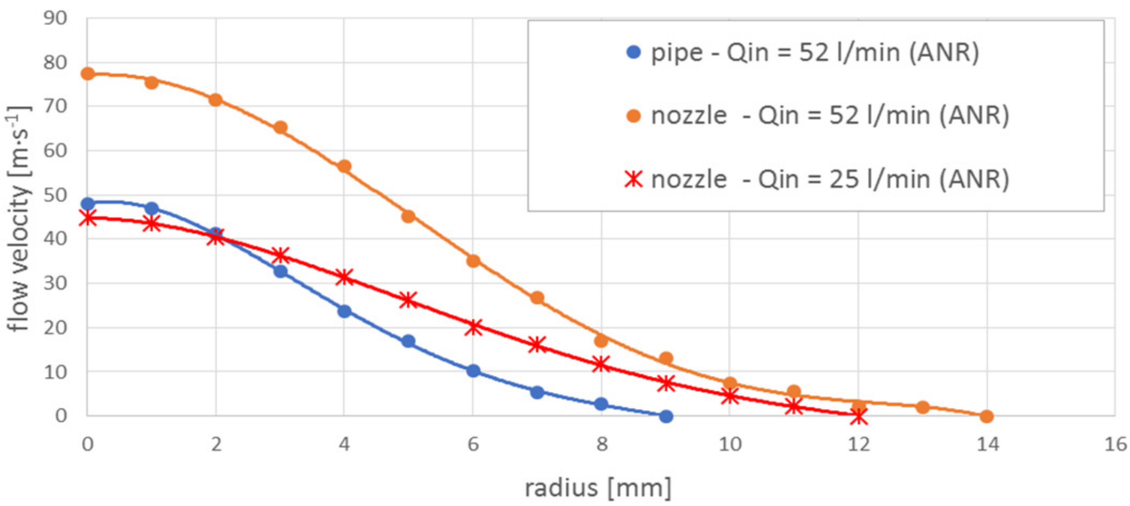

Fig. 6. Velocity profile

The measurement results are shown in the graph in Figure 6. It can be seen from the graph that the velocity in the axis of flow at the outlet of the tube is $48\ m \cdot s^{-1}$. Upon discharge from the nozzle, the maximum speed is $77.5\ m \cdot s^{-1}$. There is also a difference in the stream dimension. In the case of the outflow from the tube, the radius of the stream is $9\ mm$, with the nozzle it is $14\ mm$. From the comparison follows that, a smaller input flow rate is needed to achieve the same cooling effect when using the nozzle. Input flow was therefore reduced to approximately half - $25\ dm^3 \cdot min^{-1}\ (ANR)$. In this case, the maximum speed is $44.8\ m \cdot s^{-1}$ and the radius of the stream is $12\ mm$. This means that using a high efficiency nozzle can reduce air consumption by half. In addition, the cooling effect will increase as the drill will be cooled over a length $24\ mm$ instead of the original $18\ mm$.

Table 2. Air flow from the tube

tube, inlet flow (air consumption) $52\ dm^3 \cdot min^{-1}\ (ANR)$, $L = 35\ mm$		
radius - r $[mm]$	velocity - v $[m \cdot s^{-1}]$	Output flow – Q_N $[\ dm^3 \cdot min^{-1}\ (ANR)]$
0	48	-
1	46.9	8.9
2	41.3	24.9
3	32.7	34.9
4	23.7	37.2
5	17	34.5
6	10.2	28.2
7	5.3	19.0
8	2.8	11.5
9	0	4.5
Total flow rate		203.6

From the results of measurement of the velocity profile was also calculated a total flow rate at a distance of $35\ mm$ from the tube or nozzle. The total flow was determined as the sum of the flows through the individual annuluses calculated according to the formula

$$Q = \frac{v_2 + v_3}{2} \cdot \pi \cdot (r_3^2 - r_2^2)$$

It has already been mentioned that in the outflow from the nozzle there is a sucking of surrounding air. This is also the case when the air flows out of the tube. At an inlet flow of $52\ dm^3 \cdot min^{-1}\ (ANR)$ the flow is increased to approximately $200\ dm^3 \cdot min^{-1}\ (ANR)$. In the case of a nozzle at the same inlet flow it is up to $650\ dm^3 \cdot min^{-1}\ (ANR)$. At half-consumption, the total flow rate is approximately $365\ dm^3 \cdot min^{-1}\ (ANR)$.

Table 3. Air flow from the nozzle

Nozzle, inlet flow (air consumption) $25\ dm^3 \cdot min^{-1}\ (ANR)$, $L = 35\ mm$		
radius - r $[mm]$	velocity - v $[m \cdot s^{-1}]$	Output flow – Q_N $[\ dm^3 \cdot min^{-1}\ (ANR)]$
0	44.8	
1	43.5	8.3
2	40.5	23.8
3	36.3	36.2
4	31.5	44.7
5	26.2	48.9
6	20	47.9
7	16.3	44.5
8	11.9	39.9
9	7.3	30.8
10	4.5	21.1
11	2.3	13.5
12	0	5.0
Total flow rate		364.5

From the above results, it is clear that even at half the consumption it is possible to achieve better cooling efficiency.

Therefore, the first recommendation was to equip the machine with high efficiency nozzles. Due to its size, the nozzles cannot be mounted on all applications. In these cases, there can make other arrangements.

2.2 Turn on and off the flow

At the beginning of the article, it has already been mentioned that the air flows from the tubes for cooling and blowing constantly. By switching on and off the flow, consumption can be limited only to the time it is justified. First, let us introduce the cycle. It lasts 6 seconds. The cycle begins with the drill bit moving to the workpiece - $0.5\ s$, then drilling for $4\ s$, moving back $0.5\ s$ and replacing the workpiece $1\ s$. Throughout the drilling time, the drill bit is completely out of the cooling air flow and this leads to unnecessary consumption. By switching off the airflow to this time, consumption can be reduced to only a third. For flow switching, a 2/2 valve must be included in the system and the control program adjusted.

A similar situation occurs when the chips are blown out of the hole. In this case, there is a need for a stream of air at the end of the drilling and above all after it. Even in this case, it would be enough to turn the air on for about 2 seconds.

3 Conclusion

Now we can evaluate the possible savings of air and thus of the financial losses. The above mentioned modifications are described primarily for cooling. If we make the same adjustments for chip blowing, we can express the cost of the year-round operation of the whole machine.

The Table 4 shows the price of the year-round operation of the machine in its original state and the cost of operation with nozzles, on / off variant and a combination of both.

Table 4. Year-round operation cost

	cooling	chips blowing	all machine
original state - per 1 year* $[CZK]$	6570	16220	22790
with nozzle - per 1 year* $[CZK]$	3285	8110	11395
on/off - per 1 year* $[CZK]$	2190	5407	7597
Combination - per 1 year* $[CZK]$	1095	2703	3798

*260 working days, two-shift operation (16 hours)

The table shows that by using both adjustments can be the total costs of compressed air reduced up to 83%. But it is also necessary to look at the whole matter in terms of return on investment. Only the price of the elements is counted in the next comparison. Costs for installation and adjustment time are not included. The price of one high efficiency nozzle is 1300 CZK including VAT. The price of one 2/2 valve, connector, cable and fittings is approximately CZK 1500 including VAT.

The Table 5 shows the financial savings achieved by the individual ways and the return on investment. It can be stated that in all cases the return on investment is within four months.

Table 5. Return on investment

	original state	with nozzle	on/off	combina-tion
operation cost - all machine $[CZK]$	22790	11395	7597	3798
savings $[CZK]$	-	11395	15193	18992
savings per day $[CZK]$	-	43.8	58.4	73.0
investment $[CZK]$	-	2600	3000	5600
return on investment $[days]$	-	59	51	77

From the above, the relatively significant savings of compressed air and thus the finance through simple changes are evident. At first glance it may seem that a saving of 11 000 up to 19 000 may not play a significant role in the operation of the company. On the other hand, if more than one plant is in operation, year-round savings can range from hundreds of thousands to millions of crowns.

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