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IMPACT OF FILTER CONTAMINATION ON EFFICIENCY AND EFFECTIVENESS OF AIR FILTER

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Abstract: *Compressed air is one of the main sources of energy used in manufacturing processes in various industries. Its production requires considerable financial outlays incurred on the supply of compression equipment and transmitting this medium to reception facilities. At the time of generation and transmission of compressed air there occur drops of air pressure due, among others, to: flow resistance and resistance caused by the air treatment facilities, etc. The work shows the influence of contamination of compressed air filters, after a certain time of operation, on the pressure drop in the installation. Conducted preliminary tests that measure the impact of air velocity on pressure drop. In this part of the experiment, determined the linear dependence of the pressure drop to fluid flow rate. Basic research consisted in determining the pressure drop arising on the filter correctly in the installation depending on the degree of contamination of the filter. These contaminants cause a drop in air pressure downstream of the filter, which can affect the proper operation of the equipment supplied by it.*

Keywords: Compressed air, Pressure drop, Loss, Installation, Energy savings.

1. Introduction

Compressed air is a very widely used energy medium used in various industries (e.g. in the chemical, food, pharmaceutical, electronics, or lacquering industry). The basic parameter of compressed air, in addition to pressure, is its purity (Duszyński et al., 2006, Grześkowiak et al., 2014). The most common contaminants, which may affect the quality of the final product, are solid particles, oil and water particles (both in the form of vapor and aerosol). An end user of the medium is therefore responsible for determining the air quality required in the technological process. The elements responsible for the cleanliness of compressed air in the installation are filters and dryers (Perz, 2009, 2011, 2013). Selection of appropriate treatment products is dependent on the desired class of air quality.

The basic criterion for assessing the filtration materials are: filtration efficiency and flow resistance (Semkło et al., 2015). Factors, that affect these parameters, are related to the structure of the filtering septum (geometric dimensions of fibers, shape, density and surface of the filtering septum), to the parameters of the compressed air (flow rate, temperature, density, viscosity and pressure), and to the contamination (size, density, shape, type, chemical composition). Assuming constant parameters of the outside air and a steady set of contamination parameters, it can be said that the filtration efficiency and air flow resistance is a function of parameters associated with the construction of the filter. Due to the fact that the air compressor is operating in the "on - off" cycle, in the system are present variable values of the air flow, and hence the air flow rate is also variable. Thus, the filtration efficiency and air flow resistance will depend on parameters such as:

$$\varphi, \Delta P = f(d_{wł}, b, \beta, \vartheta_F)$$

where:

$d_{wł}$ - the diameter of the filter fiber, b - the thickness of the filter layer,
β - the packing density of the filter layer, ν_F - air flow velocity.

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For these considerations, it was assumed that the fiber thickness and the initial thickness of the filter layer is constant due to the use of a particular type of filter. Also, the density of non-woven filter is assumed as a constant value. In the case of using in the installation a new filter, flow resistance slightly varies taking a specified initial value. This generates a pre-established minimum pressure drop without significantly affecting the energy consumed by the compressor. However, during operation of the network, the contamination emerging in the filter cause the formation on its surface a layer which alters the filtration efficiency and increasing the resistance of the filter. To ensure proper performance of the installation, the compressor must therefore overcome air resistance, which will result in increased energy consumption of the network (Dittmer et al., 2016).

The work shows the influence of contamination of compressed air filters, after a certain time of operation, on the pressure drop in the installation.

2. Experimental part

2.1. Research subject

In all filter applications, the contamination of the air supply can cause performance degradation of the installation, which in turn will translate into higher costs associated with increased pressure of the compressor. The magnitude of this decrease depends on the kind of the filter, and, above all, on the filter layers constituting the replaceable cartridge. A proper selection of materials forming the filter layer should provide an adequate air quality, with a minimum pressure drop, and hence with minimal performance degradation. The filter material in the tested filter is a filter system consisting of four layers reinforced by a layer of perforated steel. The outer portion of the filter is formed by a double layer of polyurethane foam and a layer of paper of cellulose fibers. Another part of the filter is reinforced glass fiber. The inner part consists of a paper layer, which prevents direct contact of the filter material and the steel core of the filter. The whole is protected by a metal, sealed housing (Fig. 1).

Fig. 1: Object of research 1 - tested filter, 2 - differential pressure gauge.

2.2. Measuring station

Filters were exploited in the actual compressed air installation. The screw compressor was a drive, and before the compressor installed dust pre-filters (Fig. 2).

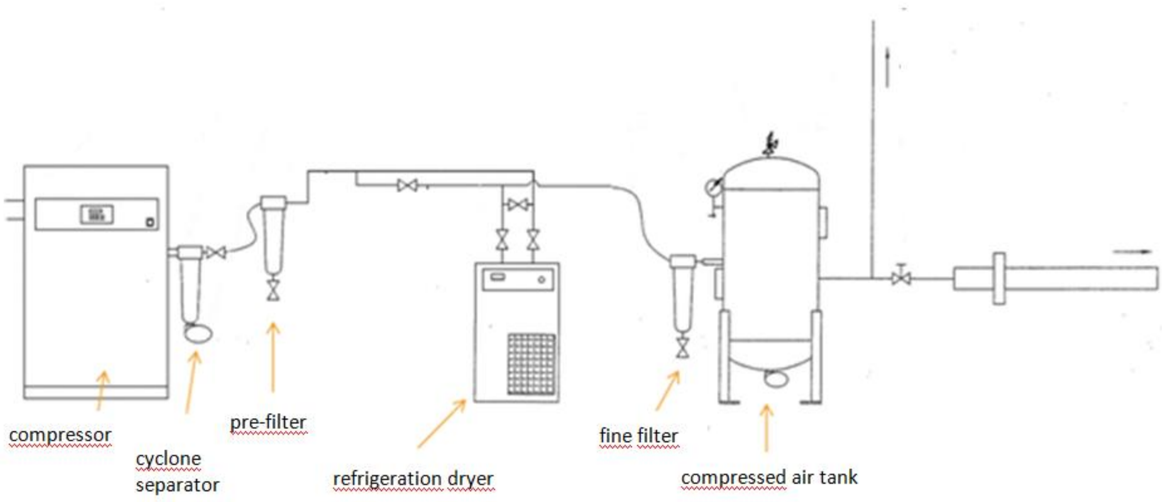

Fig. 2: Real installation of compressed air (Perz, 2013).

The rest of the installation is used for air treatment and behind the compressor installed cyclone separator, the task of which is to separate the mixture of water and oil from air. Another element is a pre-filter, which roughly separates larger particles of solids, oil and water. In a further step of treatment a refrigeration dryer was used. Further the tested fine filter is used, whose task is to clear the air from debris particle (maximum particle size is equal to 1 μm). In the case where there is a need for sterile air, upstream of the device installed a filter with active carbon.

2.3. Methodology of research

The study was based on measuring the pressure drop behind the tested air filter. For this purpose, a differential pressure gauge, with a measuring range 0 - 160 bar, was used. The variable for the study was the air flow rate, which was measured by the orifice plate. Contamination of the filter was simulated by the reduction in the flow field of the air stream. The operating pressure, during the experiment, was set at 10 bar. The object being tested was fine filter - it allows to capture particles of solids with dimensions less than 1 μm.

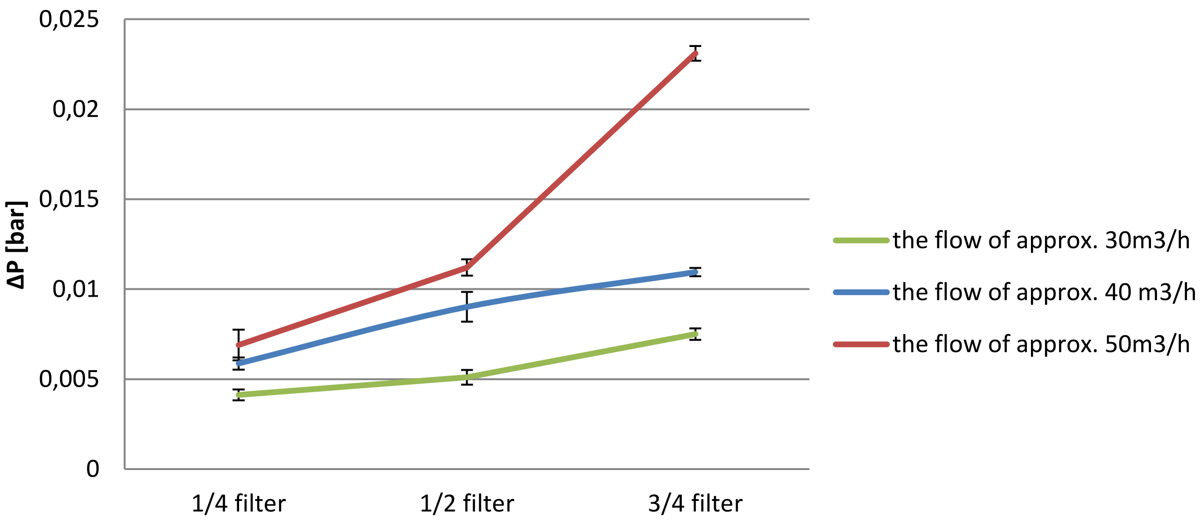

Fig. 3: The dependence of the pressure drop across the filter from the air filter contamination.

The pressure drop across the filter was tested according to the simulated contamination of the filter, and also depending on the speed of the air flow. At a given pressure (10 bar), the flow rate will depend on the diameter of the pipe used in the installation. In preliminary studies carried out in this experiment (due to the reduced volume of the work, it is not presented herein), we investigated the effect of different speeds of the compressed air at a pressure drop of clean filters. We have found that the pressure drop is linearny dependent on the fluid velocity and with increase of this velocity the pressure drop also increases. During the execution of fundamental research, as can be seen from the graph, pressure drop depends on both, the filter contamination and flow velocity of air in the system, wherein the drop is greater the more contaminated filter has been used. To prevent the growth of flow resistance, it is worth to consider reducing the speed of air flow by increasing the diameter of the flow. Increasing the flow resistance in the installation resulting in increased work of the air compressor, which significantly affects the costs of the production process. In the compressed air installation, depending on the expected class of air cleanliness, a multistage filtration system is used. It results in a larger number of filters with different parameters, but the pressure drop always occurs on them. Therefore, the final value of air resistance is the sum of all the pressure drops on individual filters and reuse devices. It should therefore ensure the proper use of filters (correct time of the filters replace, the use of pre-filters, etc.), since this has a direct impact on energy consumption in the manufacturing process of compressed air.

3. Conclusions

Impurities in compressed air are particulate matters (dust, dirt, wear particles, rust particles, etc.), particles of moisture and oil particles. Absorption of filtering septum and the grain composition of dust, which flows to it, determines the working time of the air filter. The appearance of contamination on the filter leads to an additional layer, affecting significantly the resistance of air flow through the filter. Increasing this parameter lowering the air pressure behind the filter, which in turn increases the power demand of the compressor. Therefore, it is important to monitor air pressure drops in the filter during operation. Equally important is the recognition of contamination emerging in the installation - in the case of the food and pharmaceutical industry, in situations where the air is in direct contact with the product, the appearance of oil in the compressed air is not permitted.

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