STUDY AND IMPROVEMENT OF THE QUALITY OF COMPRESSED AIR TREATMENT IN COMPRESSOR UNITS WITH THE DEVELOPMENT OF A TECHNICAL SOLUTION

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Annotation
Modern production processes are becoming increasingly complex, resulting in an ever-increasing rate of growth and the constant improvement of technological equipment.

Many important components and units in the production process are pneumatically driven, and compressor equipment is responsible for their operation.

Compressed air is one of the most common energy carriers in any industrial plant. And the combination of devices associated with its processing and distribution, including compressors, heat exchangers, cleaning and drying devices, transport and distribution communications, is a rather complex and energy intensive industrial system, whose level of perfection and operation depends on the performance of technological processes where compressed air is used.

In this paper we examine the current problems in compressed air treatment in compressor installations.

Keywords: air supply, pneumocyclone, centrifugal force, filter, air column, air flow, compressed air cleaning, compressed air quality, air mix.

INTRODUCTION

The design, operation and research of air-supply systems for industrial plants is one of the top priorities for virtually every industrial engineer, both directly and in connection with other systems and processes (water, gas, oxygen and refrigeration) [1].
Heterogeneous systems are separated by different forces. The forces acting determine

the design of the apparatus and its application**. In** a pneumocyclone, separation **is** mainly effected by centrifugal forces**.**

Pneumatic cyclones are used successfully in many industries and show good results**.** Their advantages are their small size**,** efficiency**,** simple design and the possibility to combine them into one large complex **(**multipneumocyclone**).** However, such a simple apparatus design is characterised by a complex air dynamic process. The mode of air flow in the apparatus is turbulent, so there is a phenomenon called turbulent diffusion, which strongly affects the separation capacity of pneumocyclone **[2].**

PROBLEM DISCUSSION

Centrifugation is the process of separating heterogeneous systems, suspensions and emulsions, in the field of centrifugal forces, using solid or air-permeable walls. In apparatuses with solid walls the separation of suspensions and emulsions is carried out according to the sedimentation principle, where the action of gravity is replaced by the action of centrifugal force. Apparatuses with permeable walls separate suspensions according to the filtration principle, and instead of the pressure difference the action of centrifugal force is used [3].

The centrifugal force occurs when the centrifuge and the air in it rotate. It occurs as a force of inertia in the rotational motion of bodies, and is always directed radially from the axis of rotation to the periphery. If we denote: G - weight of the rotating body; r - distance from the axis of rotation to the centre of gravity of the body; w - angular velocity of rotation, the centrifugal force C can be determined by the following equation:

$$C = G\,\frac{\omega^2 r}{g} = GFr$$

where $\dfrac{\omega^2 r}{g} = Fr$ is the Froude criterion. It is determined by the centrifugal force, developed by 1kg of body weight, and is called the separation factor. Fr indicates how many times the centrifugal force is greater than the force of gravity.

Centrifuges can be divided into two groups according to their separation factor: normal centrifuges $(Fr \prec 3500)$ and supercentrifuges $(Fr \succ 3500)$

The centrifugal force is proportional to the value of the radius r and the square of the number of revolutions. Therefore, it is more appropriate to increase it by increasing the number of revolutions rather than by increasing the radius. The pressure increase is equally affected by increasing the number of revolutions and lengthening the radius

The product of the separation factor Fr by the solids deposition surface of the centrifuge rotor S is called the centrifuge capacity index and is denoted by Σ :

$$\Sigma = FrS$$

The performance index Σ is numerically equal to the sedimentation surface of the settling tank in which the same performance is achieved as in the centrifuge. The value Σ describes the influence of the design factors on the centrifuge's ability to separate a given heterogeneous system [4,5].

MATERIALS AND METHODS

In a pneumatic cyclone, three main areas are formed during its operation, which are characterised by different flow patterns:
1. internal area;
2. external area;
3. the walled area.

The inner area is a cylindrical vortex with an air column on the axis. The presence of an air column depends on the operating mode of the cyclone, namely the inlet pressure. At normal operating pressure, an air column can be seen which will have a height equal to the height of the pneumocyclone from the bottom discharge to the top discharge.

An annular vortex forms between the inner and outer areas, with air moving in both directions at the same time.

In addition to the main downward and upward flows, there are numerous local circulations and turbulent mixing in pneumocyclones. All this determines the complexity of pneumodynamic processes and influences the separation of disperse systems in pneumocyclones [5].

At first, when air is supplied to the empty pneumocyclone, its flow from the feeder nozzle hits the wall of the pneumocyclone and spreads over it in a thin layer, expanding as it moves away from the feeder point. The upper part of the flow meets the resistance of the cover and runs onto the lower surface of the latter. The downward flowing part of the flow spirals along the walls of the cone to the sand nozzle, through which only part of the total flow exits, so the pneumocyclone quickly fills with rotating air and along its axis a rotating flow is formed, directed towards the discharge nozzle. Progressive movement of the external flow from the feed point to the top of the cone is also due to the reduced radius of rotation and friction against the walls, causing a

reduction in pressure at the bottom of the cone compared to the pressure at the top at the same radius. Near the axis of the pneumocyclone, the centrifugal force becomes so great that the air breaks and an air core (vortex cord) in the form of an air column is formed.

In this way, the pneumocyclone has two main flows rotating in one direction - an external flow that has a downward spiral and an internal flow that spirals upwards to the discharge spout. The external flow, approaching the top of the cone, divides into two parts: the lower part, which, without changing the direction of forward motion, leaves the pneumocyclone through the sand nozzle, and the upper part, which forms the internal flow, changing the direction of forward motion. A closed circular vortex is formed between the outer and inner streams at a level slightly below the end of the discharge nozzle, in which air simultaneously with rotation around the pneumocyclone axis moves on the outer side towards the sand nozzle and on the inner side towards the lid. In addition to these streams there is the so-called under-cover stream, formed by a part of the original feed flowing around the lid, which is then directed down the walls of the discharge spigot and goes into the discharge together with the internal stream.
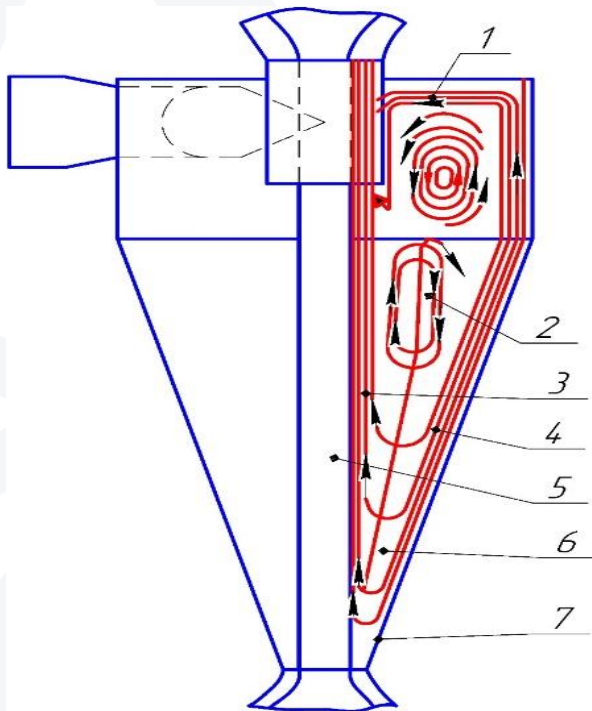

Fig. 1 - Schematic of air movement 1 - under-cover flow; 2 - closed circular vortex; 3 - internal flow; 4 - external flow; 5 - air column; 6 - surface of zero axial velocities; 7 - part of external flow discharged through sand nozzle

In the near-wall region there is a strong drop in velocity of the medium and the particle. In this area there is a viscous sublayer which is very thin and can sometimes be neglected. Dispersed particles either settle on the wall and continue their movement down to the outlet or hit the wall of pneumocyclone and continue their movement depending on the force, under the influence of which they are (centrifugal force or radial flow force) [6].

RESULTS AND DISCUSSION

The developed device is designed for the secondary treatment of primary treated air in the area of air purification in mining operations.

In industry, pneumocyclones of various designs are commonly used for the classification of two-phase air of heterogeneous composition, which can be used in the chemical, coal and beneficiation industries to produce final products of varying degrees of separation.

Development of a pneumocyclone with an air-mix filter unit that produces a higher quality filtrate by effectively recycling the primary treated air in the space of an additionally installed cylindrical chamber.

Pneumatic cyclone with an air mixture filter unit, consisting of a cylindrical-conical shell, a tangential inlet, a discharge branch pipe, a sludge branch pipe, an additional cylindrical chamber with a discharge branch pipe and a cylindrical-shaped filter in the upper part.

The addition of a cylindrical chamber with a cylindrical filter, an outlet spigot and an easily removable top lid to the pneumocyclone facilitates efficient secondary treatment of the primary treated air.

The developed device is explained by the drawing in Fig. 2, which shows a general view of the device.
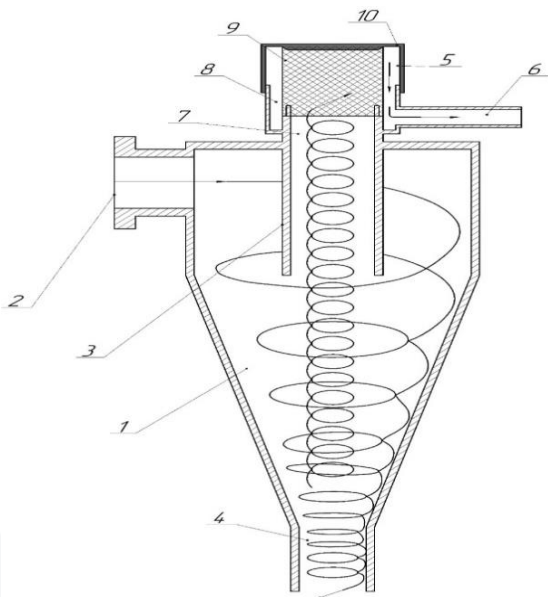
Pneumocyclone with air filtration device consists of cylindrical-conical shell 1, tangential inlet 2, discharge outlet 3, sludge outlet 4 and primary air chamber 7, additionally mounted on top of secondary air chamber 8 cylindrical chamber 5, discharge outlet 6, cylinder-shaped filter 9 and upper cover 10, connected to secondary air chamber 8 by threaded joint.

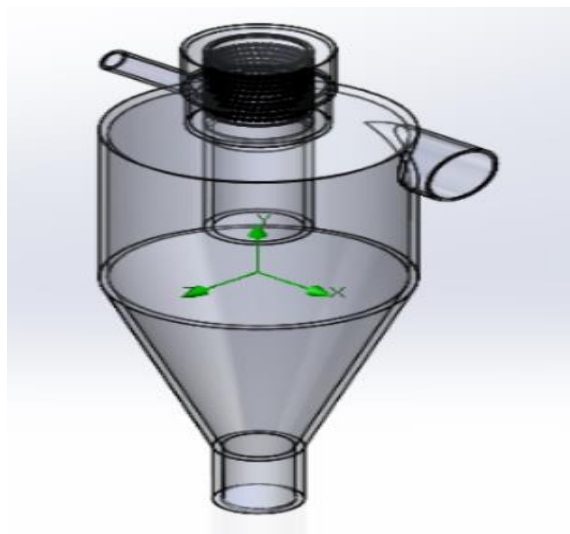A pneumatic cyclone with an air-mix filter unit works as follows

Two-phase air, entering the cylindroconical shell 1 through tangential inlet 2, under pressure is divided into two components: the solid phase (sediment, sludge), having specific gravity greater than specific gravity of air, is displaced to the wall of pneumocyclone and from there directed to the sludge branch pipe 4. And the air phase (primary purified air) goes to the discharge branch 3 and under pressure enters into

the chamber for primary purified air 7, and the filtrate through the filter 9 enters into the chamber 8 for secondary purified air. From there the purified air is routed to its destination via the outlet 6. When the filter 9 is clogged with sludge, sediment, and the cover 10, connected by threaded joints with each other and with the additional cylindrical chamber 5, can be easily removed, after which the filter is cleaned and put back in its place. Thus, by rationally positioning the filter 9 in the additional cylindrical chamber 5, efficient cleaning of the air phase of the primary cleaned air mixture from the solid contents is ensured [7].
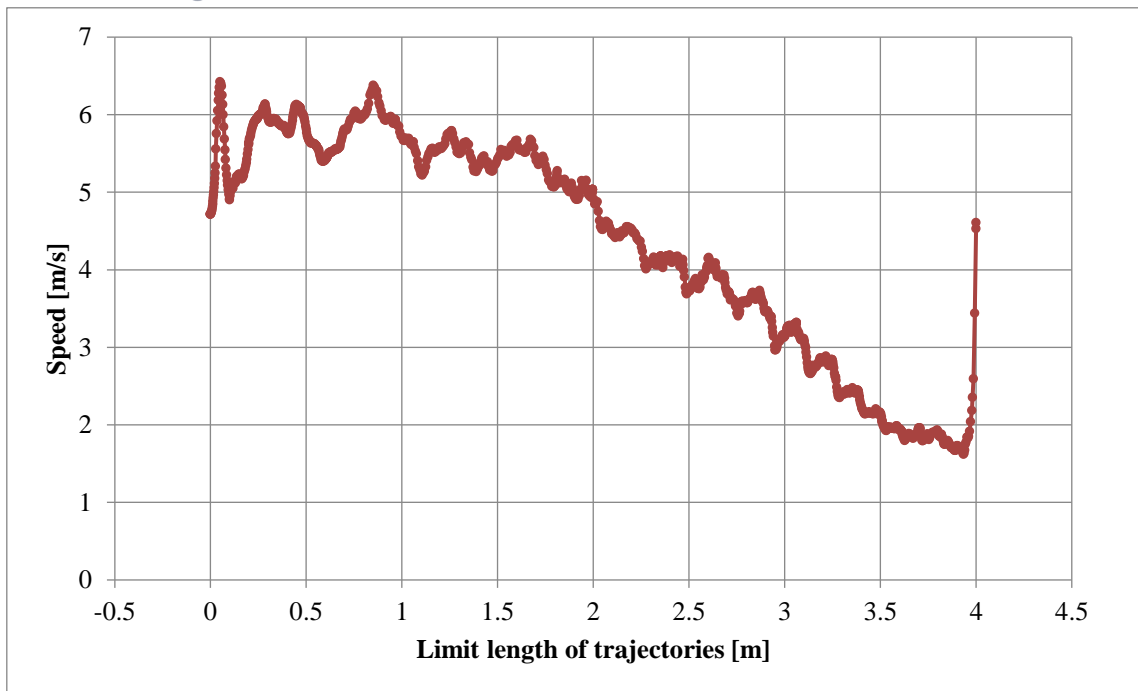

Fig. 2 - Pneumocyclone with air-mix filter device

Fig. 3 - 3D model of a pneumocyclone with an air-mix filter device
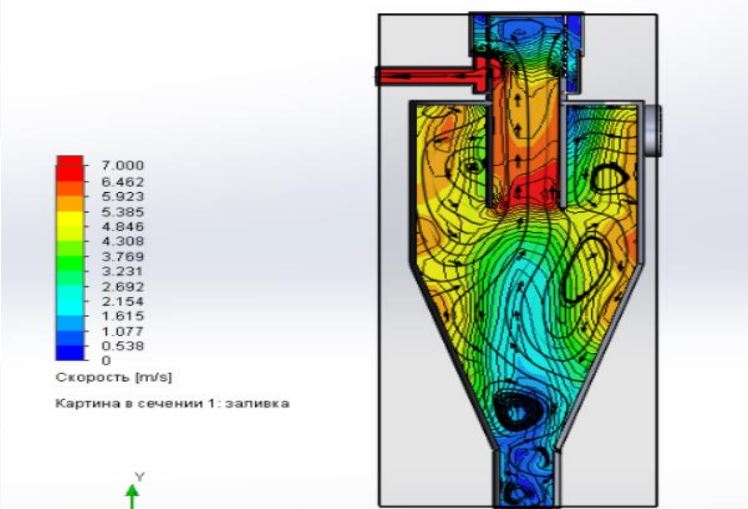
Fig. 4 - Received results of analyses of air-mix filter cyclone using Solidworks Flow simulation software.

Fig. 5 - Diagram of compressed air velocity change in a pneumatic cyclone with air filter device when analysed in Solidworks Flow simulation software

CONCLUSION

The introduction of the developed device facilitates:

1. Improves compressed air quality.
2. Increase the utilisation rate of compressor units;
3. Reduce the likelihood of sudden failures and thereby improve workplace safety and eliminate significant damage;
4. Saves the personal cost of replacing air filters, as the filter fitted to the upper extra cylindrical chamber can be used many times over.

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