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The problem of highly effective cleaning of air from dust

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Abstract. This article deals with the problem of providing high performance apparatuses for cleaning air from dust in various branches of industry in order to reduce hazardous emissions to the level of conforming to the sanitary-hygienic norms. The article describes new trends in the development of dust catching apparatuses based on the use of centrifugal-inertial forces, permitting to improve significantly the dust catching efficacy.

Key words: dust catching, air cleaning, pollution, centrifugal, cyclone

Problem definition. The present ecological situation in Ukraine (excessive concentration of environmental threat productions, outdated and inefficient nature of protection equipment at the closing stages of technological chains, engineering system insecurity, low level of enterprises' efficiency in the increased environmental risk conditions etc.) determines the urgency of constant utmost attention to the activities aimed at ecological security of the country. Heavy concentration of agriculture and industry has caused disastrous air, water and soil pollution. Present ecological change scales have created a real hazard to public health and pose a threat to the life of Ukraine citizens. The state of health of society is one of the basic environmental quality criteria. In the population common sicknesses rate those diseases are prevalent which are the result of anthropogenic environmental pollution, particularly of atmospheric air contamination. Impartial medical data indicate the constantly growing influence of ecological factors on the physical potential of our society.

Upon the whole, ecological situation in Ukraine can be characterized as crisis. In 2012 the average annual dust concentration (undifferentiated with respect to composition) exceeded the ecological safety standards in 23 Ukrainian cities. [1,2]. According to the Ministry of Statistics (State Statistics Service of Ukraine) information, in 2012 total volume of hazardous substances emissions into the atmosphere accounted for 6,04 mln t, at that 4,16 mln t – from stationary sources of pollution, and 1,88 mln t – from traffic (non-stationary sources).

The data of official state statistics and from other special researches indicate that environmental changes are closely related to the state of health of the population. Dust lungs pathology, first of all pneumoconiosis and chronic dust bronchitis, have been ranking high traditionally in the structure of population professional morbidity for many decades. And so in 2012 in Ukraine the highest proportion manifested itself of pneumoconiosis and chronic bronchitis at 27,5% (710 cases) and 21,8% (564 cases) per 100 thousand citizens. The diseases of allergenic origin are typical of the most ecologically dependent types of pathology. In comparison to 2011, in 2012 the incidence of bronchial asthma among Ukrainian population increased from 423,3 to 458,2 cases per 100 thousands of citizens, i.e. by 8,4%. There is a direct close correlation between the atmospheric pollution levels caused by allergenic action substances (dust) and the incidence of bronchial asthma among Ukrainian population.

For many years the initial population sickness rate in Lviv Oblast' have been higher than the average one Ukraine-wide, and even higher than in Donetsk-Dnipro region. As it has been shown by the results of the researches [4], in the conditions of Lviv Oblast', even against the background of medical aid level increasing (twofold), there is a growth of general sickness rate among the adults by 18%, and among the children by 7%, which is closely related to the environmental pollution level. Dust emissions have dramatically worsened the ecological state of the environment. For this reason, recently in all countries of the world much more attention has been devoted to the issue of dust emissions under various technological processes.

It is essential to discover correlation between atmospheric pollution in the regions of Ukraine and population sickness rate growth, also to perform the present dust cleaning apparatuses analysis and to suggest high-performance dust catchers for air from dust cleaning.

Therefore, the task of our researches was to formulate the theory of dusty gas stream flow in the apparatus casing and on its significance for the choice of optimal dust cleaning apparatuses structure.

Recent Research Analysis. The analysis of famous dry dust cleaning methods has shown that despite high-performance catching of coarsely dispersed dust particles, they cannot provide fine-dispersed fraction cleaning by more than 85%, and a number of constructive improvements leads to a considerable complication of dust cleaning schemes.

The greatest achievements in centrifugal catching of solid particles from gas flow are marked in the part of apparatus implementation (engineering), but not scientific elaborations, [3-6] which is explained, on the one hand, by the accumulation of industrial apparatuses operation long experience, and on the other – by the considerable complication of description of certain phenomena and properties of heterogeneous systems: rigid body – gas in centrifugal field,

Literary sources analysis allows us to draw a number of general conclusions concerning our research: aerodynamics data have a solely experimental nature; there are no theoretical connections whatever, which would allow to generalize the collected experimental material and to detect the major defining the "screws" in aerodynamic properties; if there were such connections, we could dispense with experiments in every specific case, and their availability would be a solid foundation of different screws selection and computation methods. It is essential to devise different constructions in the "screw" use of optimum variants from the viewpoint of security and economic efficiency of regulation; computational methods must in terms of quantity take into consideration the interference conditions of all the ventilation system elements; the ultimate goal of the research must be the getting of simple and infallible "screws" for computation and selection methods.

Main Research Material Statement. Air from dust scrubbers efficacy and economical efficiency is most frequently determined by the right choice of all the automatic regulation elements. The main part of such regulation tasks is connected with amount changes of the air, which go through different branches and separate system elements [8].The control device is an element for incoming flow swirl – a "screw" of different constructions.

The data availability about aerodynamic properties of the "screw" is the necessary prerequisite for the right choice of the elements for incoming flow swirl (the "screw") in conformity with specific regulation conditions. In practice, the designing of cases, when they are chosen to match the size of air ducts and equipment in the "screws" installing places, are not infrequent

In the suggested by us dust catcher construction the conchoidal inlet is just the example of direct placement of such a "screw" in the dust catcher inlet.

Aerodynamic properties materials often have experimental nature and cannot be generalized for other constructions. In the works devoted to "screws" computation, the acquired experimental data apply to any constructions. At the same time their practical use conditions, including reciprocal influence of "screws" and other system elements, with which they co-operate, [9-13] are left out of account. The existing "screws" methods and recommendations are either complicated, or have a very general nature.

The multiplicity of "screws" constructions dictates the need for such solutions that may allow conducting computations sufficiently simply and with good reasons for it, depending on specific regulation conditions.

The rectangular and straight "screws" engineered today, which are intended for full industrial production, structurally differs from those, whose aerodynamic properties are known. For this reason, the fact that American companies recommending their products demonstrate a radically different selection and computation techniques, is of interest.

Aerodynamic "screws" properties are expressed by their inner and working characteristics. Inner aerodynamic "screw" characteristic is determined by the relation:

$$\zeta = f(\alpha), \tag{1}$$

where: ζ– "crew" resistance coefficient; α – trailer dead angle, deg.

Since we open the "screw" in order to increase consumption, the pressure on the "screw" differential is decreasing, and pressure loss in air duct is increasing proportionally to the velocity square of the air, which goes through either naturally or the "screw" characteristic should be considered in correlation with the characteristic of the system, in which it is used [15,18]. This characteristic, which is essential for regulation processes computation, is called the working aerodynamic characteristic. Its formation by known inner aerodynamic characteristic can be executed by the formula:

$$\frac{v_1}{v_0} = \sqrt{\frac{\Delta H_1}{\Delta H_0} \cdot \frac{\xi_{p,y} + \xi_0}{\xi_{p,y} + \xi_1}}, \tag{2}$$

where: υ_0, ΔH_0, ζ_0 – air consumption, pressure loss in the section, which is adjusted, and open "screw" resistance coefficient $\alpha=0$, respectively; υ_1, ΔH_1, ζ_1 – the same in any of "screw" trailer intermediate positions; $\zeta_{p.y.}$ – section, which is adjusted, resistance coefficient, attributed to the velocity in the "screw" cut.

Practically, the "screws" are used for the consumption control in the branches by constant general drop and: $\Delta H1/\Delta H0=1$. Thus working "screw" characteristic computation is made by the formula:

$$\frac{v_1}{v_0} = \sqrt{\frac{\xi_{p,y} + \xi_0}{\xi_{p,y} + \xi_1}}. \tag{3}$$

If in formula (3) the close “screw” resistance coefficient $\zeta_з$, is taken into consideration, $\frac{v_1}{v_0}$ v_1/v_0 will express the so-called air-sweeping, or the amount of air, that go through the close “screw” with respect to the overall consumption through the open “screw”. It is obvious that air-sweeping through the “screw” is the function of total resistance of the section, which is adjusted. The stronger resistance is, the air-sweeping is more intensive for one and the same “screw”.

The graph of Figure 1 represents the quantity of air-sweeping through the close “screw” computational dependence on the section, which is adjusted, resistance coefficient $\zeta_{р.л}$. In addition to that, the meanings of $\zeta_{р.л}$ are applied to the velocity in the flow area of the “screw”, which adjust. According to the graph data, air-sweepings depending on the adjusted resistance of the section and the installed “screw” size, may differ considerably, and thus they cannot characterize the “screws” embodiment quality.

The “screw” resistance coefficient at its closing is the basic quantity, which determines the tightness of “screw” closing. Perfectly executed “screw” has $\zeta_з$, real “screws” – finite quantity $\zeta_з$.

If we are to characterize air-sweeping, as it is practically accepted, by the percentage from total consumption when the “screw” is open, it should be considered by equation $\zeta_{р.у.}=0$, and the air-sweeping should be calculated by the formula:

$$\frac{v_1}{v_0} = \sqrt{\frac{\xi_0}{\xi_1}}. \tag{4}$$

At the same time, the minimum air-sweeping quantities will be obtained. For any installation these quantities will be higher.

It is known that for the regulation convenience it is necessary to adjust the consumption relative change dependence on the relative “screw” thread to, most of all, the approximate to the rectilinear [17,19,20].

The evaluation of maximum force (moment) for “screw” drive is the necessary condition of the actuating mechanism power right selection. The strongest force on the actuating mechanism will be the case, when:

$$M_{п} = M_{дин} + M_{гв}\text{, } kgm \tag{5}$$

where: $M_п$ “screw” drive moment, *kgm*; $M_{дин} = cbF\Delta H$ – rotational moment which arises from the action asymmetry of current intensities, flowing with respect to “screw” axis (the resultant of these forces does not lie on the “screw” axis, but is situated at some distance from it, which depends on the rotation angle of the “screw” and its form); *c* – empirical coefficient, dependent on the rotation angle and the form of the “screw”; *b* – “screw” width in the perpendicular to rotation axis direction, m; *F* – “screw” area, m^2; ΔH – the pressure differential on the “screw”, *kg/ m*^{2}; $M_{ст}$ – the force, required on the “screw” rotation in the still air, *kgm*.

Relation (5) allows us to find the nearest quantity of the forces on the actuating mechanism by experimental evaluation $M_{ст}$ and *c* for this “screw” construction.

In the practice of engineering, in most cases the air motion, through different obstacles, apertures etc, resistances quantities is conventionally characterized by resistance coefficient. General formulae of resistance take the form of:

$$\Delta H = \zeta \frac{\gamma \omega^2}{2g} Па., \tag{6}$$

where : ω – air velocity in the “screw” flow area, *m/ sec*; γ – air specific weight, *kg/ m*^{2}.

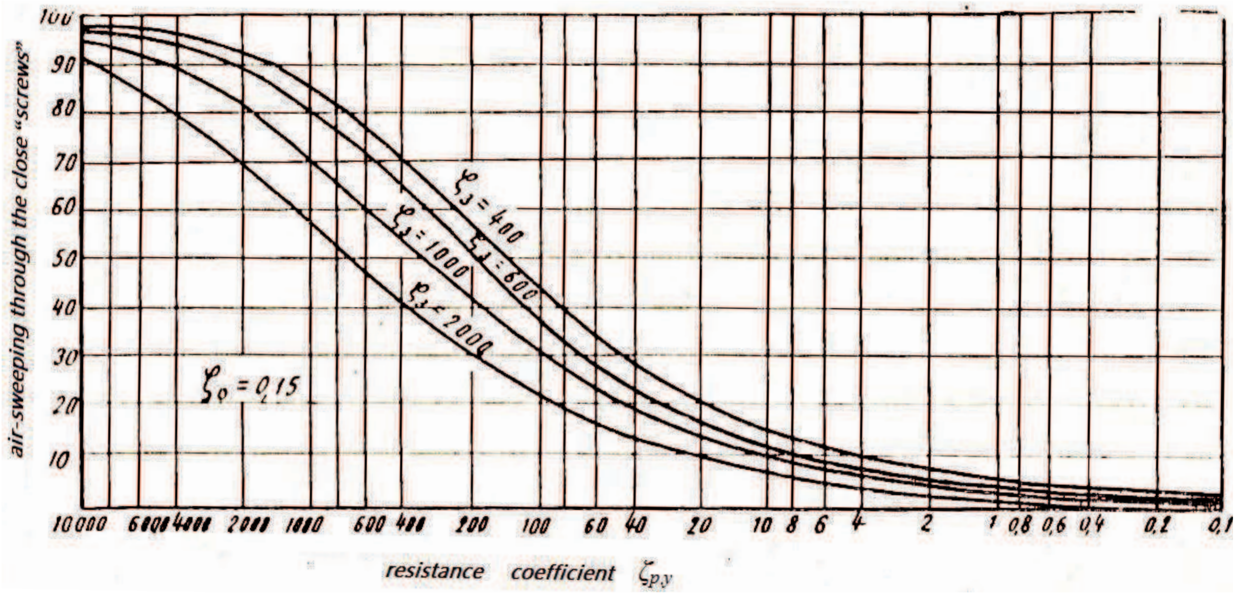


Fig 1. The dependence of air-sweepings through the close “screws”

Such formula form is conditioned by the quadratic dependence between motion resistance of the air and its velocity, which occurs by turbulent motion, when the inertial forces, arising in the flow, dominate the viscous forces. Such an air motion mode is commonly observed, when different obstacles encountered on the motion path are flown around.

In its general form the resistance coefficient consists of the friction resistance coefficient and the form loss coefficient. In the case under our review the first coefficient quantity because of the "screw" trailer narrow width is low in contrast with the second one, which takes the "screw" choking effect into consideration. That is why, in all the subsequent reflections, the form loss quantities determined from the difference of pressure loss between the cuts with the fields of velocity, which evens, before the "screw" and after it, are the only issue [22]. The effect of closely located elbow pieces or obstructions, disturbing the equal velocity distribution, is specifically examined.

It is known that resistance coefficients are independent of both Reynolds *Re* and Mach numbers *Ma*. As a rule this dependence is not observed, when Reynolds number is large (turbulent motion). Its character is determined by the nascent state of flow separation and vortex formation and their subsequent development. The more severely the flow in local resistance is deformed, by the smaller *Re* numbers the vortex and separation are formed, and thus we observe the quadratic resistance law. The "screws" are usually used for the consumption regulation in the air ducts of large sizes, that is why their sizes are also large in most cases. As a result, we may assert that the automated modeling condition should be adhered to for the majority of the folding «screws» at the considerable air flow velocities. More detailed research of this issue was not set as this paper object.

The resistance coefficient dependence on the Mach number begins to appear approximately when $Ma > 0,6$. Since the air velocities in air dumps are incommensurable with the sound velocity, we may consider that the "screw" resistance coefficients are independent of *Ma*.

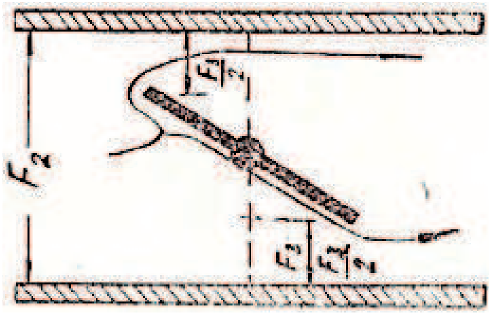


Fig 2. The air flow around the "screw" schema

Thus, these coefficients must be the functions of only geometrical parameters of the "screw". The latter are determined by the "screw" installing angles, their number and the form, and also by the "screw" design (rectangular, round, opposed).

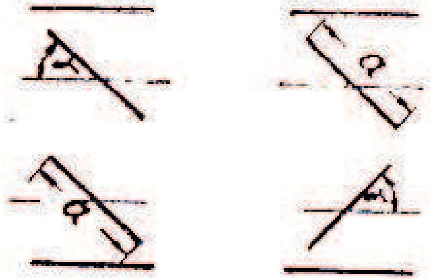
This parameter part creates one or another conditions for the air flow motion through the folding "screw" and stipulates its resistance coefficient quantity. When the air flows between the "screw" folds, the air stream narrows from air duct full cut F_2 to some free cross-sectional area plane F_3, which is generated by a certain "screw" folds installing (Figure 2). Simultaneously, the flow deviates from the rectilinear direction, while at some distance after the "screw" its inverse deviation or air duct length leveling occurs.

The availability of velocity differences in the narrow and wide cross-section results in the flow separation and vortex formation, which stipulates irreversible energy consumption. In essence, the phenomena, occurring in the examined case, are analogous to the case of the stream sudden expansion by abrupt change of cross-section for air passage and can be estimated by the dependences (7) and (8):

$$\zeta = \left(\frac{F_2}{F_{3\varepsilon}} - 1 \right)_2 , \qquad (7)$$

$$\zeta = \left(\frac{1}{n^{\varepsilon}} - 1 \right)_2 , \qquad (8)$$

where: ε – the coefficient of stream contraction, which is the result of motion inertia; $n=F_3/F_2$ – free area between the "screw" to air duct's cross-section area ratio.



a b

Fig. 3. Parallel and opposed "screws" schema: a – parallel, b - opposed

Coefficient ε – the function of installing angle of the "screws", their design and relative positions.

Correspondingly, "screws" aerodynamic characteristics of different designs are to be different. Their inner aerodynamic characteristics construction, i.e. the determination of resistance coefficients by different "screws" installing angles, comes to the quantities n and ε finding.

The value ε cannot be definitely determined as depending on the "screw" design, as the character of stream flows is various. Appealing to Figure 3, we may mentally divide the air flow, approaching the "screw", into three parallel branches with different resistances by constant general drop. The flow character and, correspondingly, also the contraction coefficients are different in different branches. The legitimacy of such division is corroborated by the studies on the hydraulic flume in order to check the air flow between the "screw" folds and behind it authentic picture.

Thus, the “sudden expansion” of the flow from the aperture, generated by fold edge and “screw” frame plate, to the intersection, which is approximately equal to the fold width, occurs in higher and lower branches (Figure 3; b). The phenomena character may be written down by the dependence:

$$\zeta'' = k_{п.p}\left[\frac{\alpha\cdot b}{\frac{a\cdot b}{2}\left(1-\sin\alpha\right)\cdot\varepsilon_0}-1\right]^2 = k_{e.g}\left(\frac{2}{n\cdot\varepsilon_0}-1\right)_2, \quad (9)$$

where: α and b – “screw” frame width and length, *m*: k$_{\text{e.g}}$. – extension graduation coefficient, or resistance coefficients relation by gradual and sudden extension; ε_0 – compression coefficient, determined by “screw” folds design.

The flow character of the stream between the folds, angularly related to each other (Figure 3; a), can be described by the dependence as extension from the pressed opening:

$$\xi' = \left[1-\frac{\frac{ab}{2}\left(1-\sin\alpha\right)\varepsilon'\varepsilon_0}{ab}\right]^2 = \left(1-\frac{n\varepsilon'\varepsilon_0}{2}\right)^2, \quad (10)$$

where ε' – compression coefficient by flow from the pressed opening, which can be determined with the help of reference book.

The phenomena, occurring air flow between parallel folds (Figure 3; a), can be described by the dependence:

$$\xi''' = \left(\frac{1}{n''\varepsilon_1\varepsilon_0''}-1\right)^2, \quad (11)$$

where: ε_0'' – coefficient, which takes incidental corner losses between the folds, and also incidental vortex formation on the edge into consideration; ε_1 - compression coefficient by flow from the pressed opening, which can be determined with the help of reference book information. In contrast to ε' it does not take account of the intrusion into the bore softening.

According to the known dependence for parallel branches by constant general drop we can write down:

for opposed and single-winged “screws”:

$$\frac{m}{\sqrt{\xi}} = \frac{m\frac{n}{2}}{\sqrt{\xi'}} + \frac{m\left(1-\frac{n}{2}\right)}{\sqrt{\xi''}}, \quad (12)$$

for parallel “screws”:

$$\frac{m}{\sqrt{\xi}} = \frac{\frac{n}{2}}{\sqrt{\xi'}} + \frac{1-\frac{n}{2}}{\sqrt{\xi''}} + \frac{m-1}{\sqrt{\xi'''}}, \quad (13)$$

in the general view:

$$\xi = \frac{m}{\dfrac{n}{2\left(1-\dfrac{n\varepsilon'\varepsilon_0}{2}\right)} + \dfrac{1-\dfrac{n}{2}}{\left(\dfrac{2}{n\varepsilon_0-1}\right)\sqrt{k_{Пp}}} + \dfrac{m-1}{\left(\dfrac{1}{n''\varepsilon_1\varepsilon_0''}-1\right)}}. \quad (14)$$

Dependence (14) can be spread on angular displacement interval $20<\alpha<70^o$. It is obvious that by $\alpha=0\div10^o$ and $\alpha=80\div90^o$ the stream flow laws, different from the one examined above, come into effect. These laws require special study.

For ζ_0 determination of close “screws” we can apply Idelchik formula, which relates to rod lattices. In the accepted by us nomenclature this dependence has the following appearance:

$$\zeta_0 = \beta\left(\frac{1}{n_0}-1\right)_{4/3}, \quad (15)$$

where: β – trial coefficient, which depends on the “screw” form.

Close “screws” resistance coefficients can be only experimentally obtained because of the fact that their quantities are determined only by “screw” fold construction and their realization quality. Resistance coefficients at the fold rotation angles close to 10^o and 70^o can be obtained only be means of the nearest values interpolation correspondingly when: $\alpha=0$ and $\alpha=20^o$, and also $\alpha=70^o$ and $\alpha=90^o$.

Thus, for computation by the dependences (14) and (15) the coefficient quantities *n*, *n”*, *ε1*, *ε’*, $k_{\text{e.g}}$ can be taken according to the known theoretical data, and ε_0, *ε”*, *β* – must be obtained as a result of the experiment. For their determination we have used experimental data on the resistance coefficients of rectangular opposed and parallel “screws” of different designs [1 – 3], and also the results of our own experiments. The technical information about these “screws” is provided in Table 1. 8 experimental arrangements were researched.

The pressure loss, caused by the “screw” installing, was determined by the expression:

$$\Delta H = (H_П^{AA} - H_П^{BB}) + \Delta h,\ Па., \quad (16)$$

where: $H_П^{AA}$, $H_П^{BB}$ – total pressures in the cross-sections AA and BB, *mm*; Δh – incidental losses, related to cross-sectional AA air duct length flow leveling, *Pa*.

Resistance coefficient is estimated by formula (6).

Since the researches were conducted on “screws” full-scale specimens, we did not manage to reach full leveling of the flow behind the “screw” because it is necessary to have long tangents of air ducts. The quantity *Δh* was estimated by Idelchik formula for losses computation by the impact in the flow with the uneven velocities profile.

Table 1.

"Screw" type	"Screw" designation	Cross-sectional area, m^2	The number of sides
Rectangular Opposed	P 700 X 500 P 1 000 X 1 000	0,35 1,0 2,43	3 6 11
Rectangular Parallel	PO 700 X 500 PO 1 000 X 1000	0,35 1,0	3 6
Round Parallel	Д 440 Д 885 Д 1 200	0,152 0,615 1,13	1 2 5

For this case:

$$\Delta h = \left(\frac{1}{n^2} + N_1 - \frac{2M_1}{n}\right)\frac{w_1^2}{2g}\gamma, \tag{17}$$

where: N_1 – the coefficient of kinetic energy in bottle neck:

$$N_1 = \frac{1}{F_1}\int\left(\frac{w_\tau}{w_1}\right)^3 \cdot dF, \tag{18}$$

M_1 – the coefficient of momentum in bottle neck:

$$M_1 = \frac{1}{F_1}\int\left(\frac{w_\tau}{w_1}\right)_2 \cdot dF, \tag{19}$$

F_1 – the most narrow cross-section area, m^2; w_τ – local actual velocity, *m/sec*; w_1 – average velocity in bottle neck, *m/sec*.

The quantities N_1, M_1, w_1 can be estimated, when we know the velocity shape in a certain selected cross-section AA on the flow extension side. The performed analysis of velocity fields, obtained at different angles of "screw" closing, shows that the velocity profile for this case can be described by the equation of such type:

$$w = A + B\sin\left(\varphi + \omega\frac{2y}{b}\right), \tag{20}$$

where: y - cross-sectional distance from air duct horizontal axis, *m*; b – air duct cross sectional height, *m*; A, B, φ, ω – empirical coefficients.

The solution of integrals N_1, M_1 for the function of the type (20) turn out to be complicated and cumbersome formulae, and because of this they are not given. When n, N_1, M_1, w_1 are known, we can estimate the value Δh by formula (17).

The measurement technique includes the following. For each of the "screw" fold rotation angles (from 0 to 90° in every 5°) the velocity fields in the selected cross-sections before and after the "screw" were taken off. All the measurements were conducted from the ventilator suction side. The possibility to control rotational speed allowed us to select different speed rates, convenient for measurements.

The experiments showed that the velocity distribution to the "screw" (cross-section BB) approximated to the profile for a fully developed flow, which occurs in long pipes and canals.

On the side and top walls of air duct in 100 – 150 mm the holes 1 mm in diameter were drilled, to which from the outside the tubes 3 mm in diameter were soldered. All the tubes were joined with each other by means of rubber and glass tubes and connected to the micro-manometer.

The correctness of static, dynamic and full resistances measurements was verified by their summation in every air duct cross-sectional point, placed 20-40 mm apart. The value of cross-sectional average velocities was verified with loss average velocity, estimated by a collector [21, 23].

The fundamental setup schema for "screws" by their full closing air-sweeping values determination is shown in figure 4. The loss measurement was conducted in tube q, the vacuum one – in camera 2. According to this information absolute air-sweeping values and also the quantities ξ were determined.

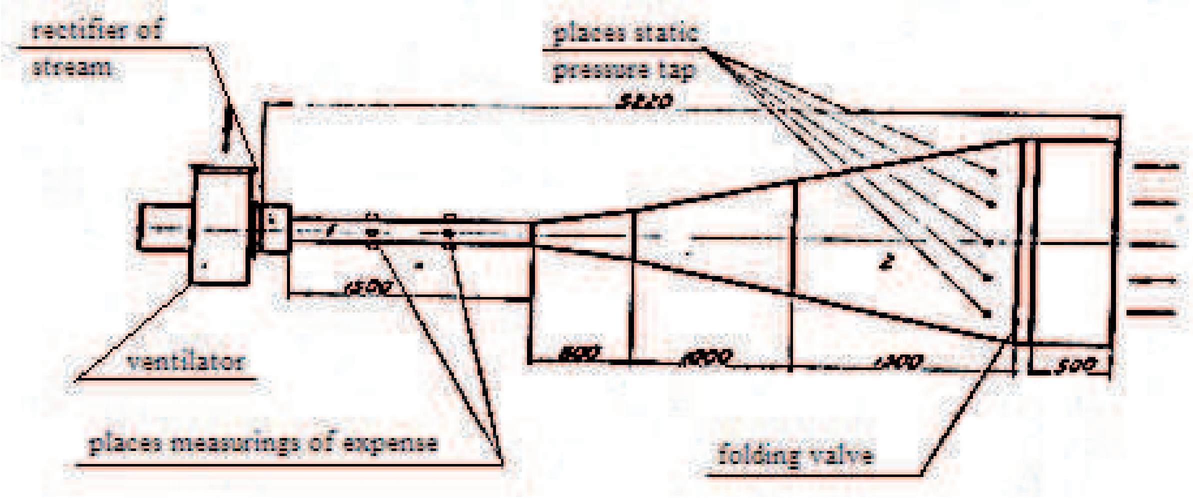


Fig 4. Experimental setup for the air-sweeping by the close "screw" schema

Table 2.

"Screw" fold rotation angle	Cross-sectional average velocity, m/sec	Wide and narrow cross-sections area ratio	Kinetic energy coefficient	Momentum coefficient	Unit resistance coefficient, related to the velocity in the "screw" flow open area
40º	10,1	0,9	0,04	1,32	0.4
60º	9	0,8	2,65	1,45	0,82
75º	6,3	0,6	5,14	2,17	1,9

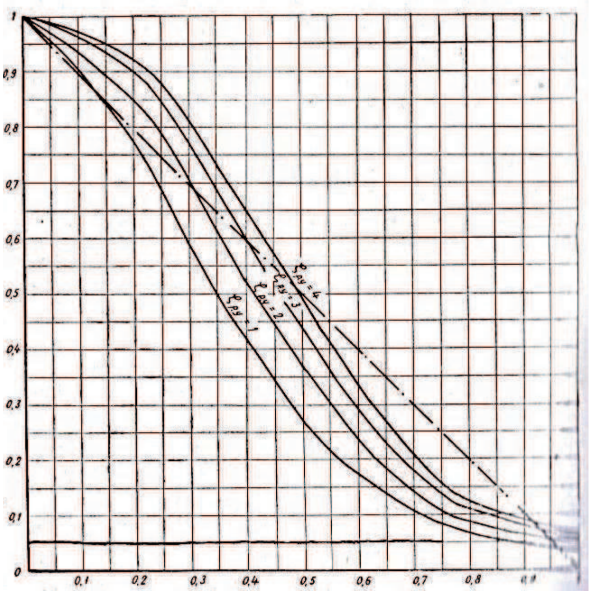


Fig. 5. The opposed "screws" performance aerodynamic characteristics

The generalization of our own experiments results and literary data allows for a recommendation of experimental coefficients' values measurements.

On the basis of inner aerodynamic characteristics, the "screws" performance aerodynamic characteristics, whose example is provided in figure 5, were constructed by formula (3). When we control air losses by means of twofold "screw", air flow inlet occurs at some angle on the "screw" folds. This circumstance stipulates specific distinction of twofold "screws" aerodynamic characteristics from the straightway one. In the case in question the mutual merge quantitatively depends on sizes ratio of twofold "screws" sections, their configuration and "screw" folds installing angles.

As mentioned above, the final force on the "screw" drive consists of M_{dyn} and M_{st} (5). The evaluation of M_{st} was carried out in the experimental way on the "screws", at the same time the lever, fastened on the driving fold axis, made the folds turn. Appropriate lever forces and shoulder lengths ℓ are listed in Table 3. The quantities $M_п$ were determined in the same way, and the maximum value for all "screw" types was fixed by α = 75º.

Table 3.

"Screw" designations	Lever forces, kg	Lever shoulders length ℓ, m	Mst, kgm	A number of folds	Mst on one fold, kgm
Р 500 Х 700	1,4	0,042	0,059	3	0,02
Р 1000 Х 1000	0,4	0,397	0,159	6	0,0265
У 1000 Х 1000	1,8	0.075	0,135	6	0,023
У 1350 Х 1800	0,8	0,397	0,318	11	0,029
Д 440	0,3	0,065	0,02	1	0,02
Д 885	3,3	0,031	0,099	3	-
Д 1200	4,8	0,031	0,15	5	-

To sum up Table 3 data, formula (5) can be represented in the form, for rectangular parallel and opposed "screws" with streamlined folds:

$$M_п = 4,3 \cdot 10\text{-}4\xi\alpha=75^{\circ}Fw_2 + 0,025\ m,\ \mathit{kgm}, \quad (21)$$

for round screws with flat folds:

$$M_п = 6,7 \cdot 10\text{-}4\xi\alpha=75^{\circ}Fw_2 + pm,\ \mathit{kgm}, \quad (22)$$

where: p – coefficient, which characterizes M_{st} on one fold and depends on the production quality of swivel blocks and fold weight.

It is significant that the quantity *cb*, which determine the distance of the application point of the resultant from the fold axis, for flat round fold it appeared to be approximately half as large, than for the streamline rectangular fold. That is why, we can concede that by the streamlined fold form, fewer forces on the movement are needed under other equal conditions, than by the flat one.

Thus, the dependences (21) and (22) allow us in the consumption way to determine forces for "screw" drive, which have folds, and equal to the examined, by different sizes and "screws" operating conditions.

For the study of aerodynamic processes, occurring in the cyclone by incoming air flow rotation around its own axis, subsequent researches were conducted in two directions; the first consisted in the research of the constructed apparatus aerodynamics by means of computer modeling, the second – in the characteristics study of the dust catcher on the test bench, which was described in chapter 3.

For the study of aerodynamic processes, occurring in the dust catcher engineered construction and for the parameter optimization for experimental researches substantiation, we have constructed the three-dimensional solid model of the dust catcher (Figure 6). In the cyclone upstream end we have placed the apparatus, the "screw" (Figure 7), primary purpose of which is to spin the incoming air stream round the nipple. The rotational frequency depends on the angle α (Figure 9) of the "screw" blades location.

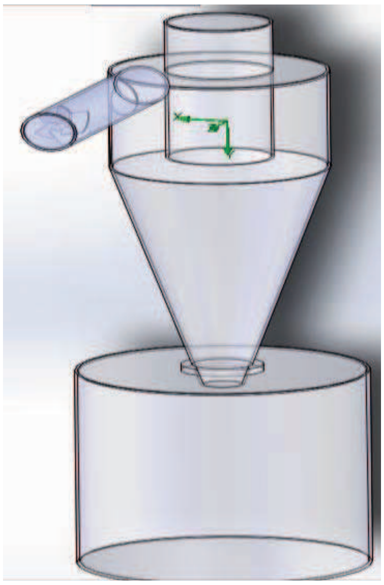


Fig. 6. Separator solid model

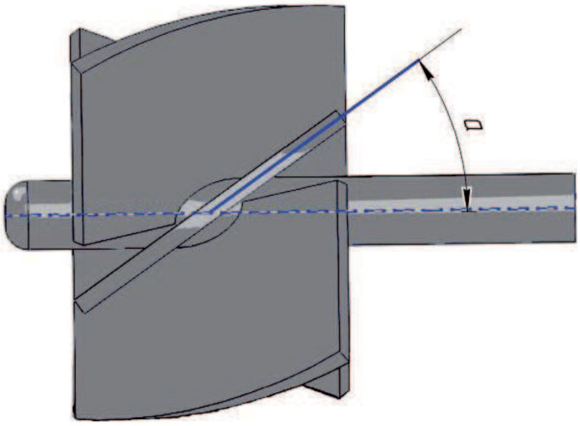


Fig. 7. Element for incoming flow spinning, the "screw'

Apparatus aerodynamic processes analysis was conducted with the i use of FlowVision, and also on the basis of the developed mathematical model, relying on the use of Navier–Stokes equations, which are described in the non-stationary formulation, mass, momentum and energy of the environment conservation laws. Furthermore, low elements state equation, and also the empiric relations of viscosity and these environment elements thermal conductivity on the temperature were applied. The turbulent, laminar and transitional (the transition between the laminar and the turbulent is determined by the critical Reynolds number value) flows are modeled by these equations. For the turbulent flows modeling (they most often occur in the engineering practice) mentioned Navier–Stokes equations were averaged by Reynolds criterion, i.e. they used the averaged on a small time scale turbulence influence on flow characteristics, and the big scale temporary changes of averaged on a small scale and by short time of gas-dynamic flow characteristics constituents (pressure, velocities, temperature) were taken into consideration by the introduction of appropriate time derivatives. As a result the equations had complementary terms – tension be Reynolds criterion.

As a consequence of mathematical modeling it was proved that by the flow rotation frequency increasing in the upstream and around its own axis, the cyclone hydraulic resistance is increasing [24]. At a blade angle of inclination, which is 15º, the apparatus hydraulic resistance practically is twice as strong as the cyclone resistance without incoming flow rotation. It is essential to study what influence on the cyclonage processes aerodynamics and the efficiency of the dusted flow clearing the incoming flow rotation has. Pro hac vice they conducted the researches at blade angle of inclination in the interval between 0 and 35º 5º Thus, they proposed the apparatus construction, the general view of which is presented in Figure 6.

The Resume And Perspectives of Subsequent Researches. At the "Electron" Production Association a test-industrial unit with a capacity rate of 600 m^3/sec for the dust suction from grinding machines, which consists of a casing, fastened on a grinder, a centrifugal-inertial dust catcher with a chevron separator, in the upstream end of which a "screw" was installed (Figure 9). It was constructed and mounted from scratch. The tool maintenance department machines connection to the ventilation system, suggested by us, allowed for an increase of general dust cleaning efficiency to 98,6%, changing hydraulic resistance and dimensions in addition to this, that is confirmed by application and test acts, and this opens up new vistas for suggested construction application and allows for a decrease of negative industrial atmospheric effusion and reduction of the threat of global consequences for future generations by means of advanced serious engineer decisions on the prevention of fine aerosol emissions.

The suggested by the authors apparatuses have found a wide use in plastic and mechanic metal working, in the building materials production when producing the bitumised perlite, ceramic tile, cement, bituminous concrete, sulfur, mud powder, saturnine red, furnace charge, potassium-magnesium, vinyl chloride, wood and metal chips, and they showed high performance at low power inputs.

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