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Assessing the Impact of the Aerodynamic Control Parameters on the Consumption of Air in Regulated Branches of Complex Ventilation Networks

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Abstract: The study presents the results of study interaction of air flow in complex ventilation systems. The study used Taylor and Maclaurin's series and Lagrange formula to create the functional connections on estimation of the impact of changing aerodynamic parameters of one or several simultaneously working regulators on the air flow distribution in mines.

Key words: Ventilating network, interaction, air consumption, depression, regulator

INTRODUCTION

Modern ventilation system of mining enterprises, developing minerals by underground mining are complex topological structures that control the distribution of the flow in which is connected with the analysis of multidimensional nonlinear systems of equations of the form:

$$\begin{cases} \sum_{i \in S} q_i = 0; \\ \sum_{i \in L} R_i q_i^2 + h_L = 0 \end{cases} \quad (1)$$

Where:

- S = 1, 2, 3,..., N; numbering of the nodes of the design scheme
- L = 1, 2, 3,..., K; numbering of independent paths in the settlement scheme
- i = 1, 2, 3,..., n; numbering of the branches of the settlement scheme
- q_i = The desired air flow in the i-th branch (m^3/c)
- R_i = Aerodynamic resistance of the i-th branch (Pa•c^2/m^6)
- h_L = Pressure characteristic of the source of thrust in the L-th path (Pa)

The solution of system of Eq. 1, formed on the basis of the first and second laws of networks, allows you to find the natural distribution of flows in complex branched systems that do not always meet the desired (Abramov *et al*., 1978; Choi and Horns, 1965; Levitsky, 2003). This is because the aerodynamic parameters of the calculation schemes (coefficients of friction, diameter of pipelines, their length and so on) are not stable and can change over time. That is why in General the set of existing methods of analysis of ventilation networks, special attention is paid to the study of the mutual coupling of the aerodynamic parameters, based on which can be built relatively simple and reliable methods of assessing the impact of regulators to change the air flow in a controlled branches. Under the interconnectedness should understand the dependence of the change of the air flow in the i-th branch of the ventilation network from changes in the aerodynamic characteristics of the regulator in the j-th control development.

In general, the interconnectedness of the aerodynamic parameters of the ventilation circuit of any complexity finds sufficiently reflected in the system of equations of the form Eq. 1. However, to move from this system to the dependency type:

$$q_i = F(R_1, R_2, R_3, ..., R_n) \quad (2)$$

Due to its nonlinearity is possible only in the case of simple relations, characteristic of the series-parallel connection of the passage. Below treated new approaches to the construction of functional dependencies, allowing to evaluate the impact of the j-th controller to the ith controlled branch.

MATERIALS AND METHODS

The building characteristics of the interconnectedness of threads based on the decomposition of the values in the Taylor series: If we turn to the ventilation system, as to the count, because the gesture some of the interconnectedness of its branches change the

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aerodynamic characteristics of the jth generation will cause a change in flow in any element of the ventilation scheme [3]. For paired links this dependence has the form $q_i = f(\alpha_j)$ in the presence of a passive control device or $q_i = f(h_j)$ using aktive regulator.

Let us have an original system of nonlinear equations of the form (1), described that the ventilation network of arbitrary complexity. If you specify the base vector $q_0=[q_{1,0},q_{2,0},q_{3,0}\dots,q_{m,0}]$ whose components are re-solution of system (1) and correspond to some fixed vector of parameters is $\alpha_o = \{\alpha_{1,0}, \alpha_{2,0}, \alpha_{3,0}, \dots, \alpha_{p,0}\}$, then, by considering the flows $q_1, q_2, q_3, \dots, q_n$ as a function of the parameters $\alpha_1, \alpha_2, \alpha_3, \dots, \alpha_p$, you can think of them in General in the form of a Taylor series:

$$q_i = q_{i,0} + \sum_{n=1}^{n} \frac{1}{n!}\left(\alpha_j - \alpha_{j,0}\right)^n \frac{\partial^{(n)} q_i}{\partial \alpha_j^{(n)}};\ i = \overline{1,m} \qquad (3)$$

Where:

- q_i = The unknown, to be determined, the air flow rate in the i-th branch (m^3/c)
- $q_{i,0}$ = The known base flow in the i-th branch, corresponding to some fixed value regulator is j,0 (m^3/c)
- α_j, j = 1, 2, . . . , p adjustable aerodynamic parameters of the ventilation system, which can be resistance branches, depression sources of thrust, airflow rates and so on
- $\partial^{(n)} q_i/\partial \alpha_j^{(n)}$ = The derivative of n-th order functions q_i the parameter is α_j

The error in the calculations can be estimated by the value of the residual term in the Lagrange Eq.:

$$\sigma(q) \le \frac{\left(\alpha_j - \alpha_{j,0}\right)^{n+1}}{(n+1)!} f^{(n+1)}(\xi) \qquad (4)$$

Where is the derivative of order (n + 1) as a function of consumption at some point , lying between the j,0 and the j. Tentatively it can be taken equal to the maximum value of the derivative of any of the orders, calculated as the base point which ultimately will increase the requirement to assess the accuracy of the calculation. Convergence will be achieved when the condition is met:

$$\alpha_j < n \cdot \left|\frac{\partial^{n-1} q_i}{\partial \alpha_j^{(n-1)}}\right| \Big/ \left|\frac{\partial^{(n)} q_i}{\partial \alpha_j^{(n)}}\right| + \alpha_{j,0} \qquad (5)$$

To determine the unknown derivatives are included in Eq. 3 and 5, predifferentiated the original system of Eq. 1 variable parameter $\alpha_j, j=\overline{1,p}$. Get:

$$\begin{cases} \sum\limits_{i\in S} \frac{\partial q_i}{\partial \alpha_j} = 0; \\ \sum\limits_{i\in L} 2R_i q_i \frac{\partial q_i}{\partial \alpha_j} + \frac{\partial h_f}{\partial \alpha_i} = 0,\ \text{if}\ \alpha_j \ne R_i; \\ \sum\limits_{i\in L} 2R_i q_i \frac{\partial q_i}{\partial \alpha_j} + \frac{\partial h_f}{\partial \alpha_j} + \sum\limits_{i\in L} q_i^2 = 0,\ \text{if}\ \alpha_j = R_i,\ j = \overline{1,p} \end{cases} \qquad (6)$$

Substituting instead of R_i and q_i their original base values, we get a linear system of equations, solving which we find the numerical values of the first derivatives. After re-differentiation will have:

$$\begin{cases} \sum\limits_{i\in S} \frac{\partial^2 q_i}{\partial \alpha_j^2} = 0; \\ \sum\limits_{i\in L} 2R_i q_i \frac{\partial^2 q_i}{\partial \alpha_j^2} + \frac{\partial h_f}{\partial \alpha_j^2} + \sum\limits_{i\in L} 2R_i \left(\frac{\partial q_i}{\partial \alpha_j}\right)^2 = 0, \\ \qquad \text{if}\ \alpha_j \ne R_i; \\ \sum\limits_{i\in L} 2R_i q_i \frac{\partial^2 q_i}{\partial \alpha_j^2} + \frac{\partial^2 h_f}{\partial \alpha_j^2} + \sum\limits_{i\in L} 2R \left(\frac{\partial q_i}{\partial \alpha_j}\right)^2 + \\ + \sum\limits_{i\in L} 4q_i \frac{\partial q_i}{\partial \alpha_j} = 0,\ \text{if}\ \alpha_i = R_i,\ j = \overline{1,p}. \end{cases} \qquad (7)$$

A similar lookup system (7) is reduced to the line of sight relative to the second derivative. Thus instead $\partial q/\partial \alpha_j$ substituted the corresponding previously obtained numerical values. Consider the algorithm for constructing a functional dependency $F_i = R_i q_i^2$ is associated with differentiation of functions of a variable parameter $\alpha_j, j=\overline{1,p}$. The researches have shown that differentiation of functions $F_i = R_i q_i^2$ corresponds to the binomial theorem decomposition of the expression $F_i = (q_i + q_i)^n$ for conditions ï ≥ 2. Therefore, it is fair formula of Leibniz and derivative of nth order from the function will be determined from the expression:

$$F_i^{(n)} = R_i \left[q_i \frac{\partial^{(n)} q_i}{\partial \alpha_j^{(n)}} + \frac{n}{1!} \frac{\partial^{(n-1)} q_i}{\partial \alpha_j^{(n-1)}} \frac{q_i}{\partial \alpha_j} + \frac{n(n-1)}{2!} \frac{\partial^{(n-2)} q_i}{\partial \alpha_j^{(n-2)}} \frac{\partial^2 q_i}{\partial \alpha_j^2} + \right.$$
$$+ \frac{n(n-1)(n-2)}{3!} \frac{\partial^{(n-3)} q_i}{\partial \alpha_j^{(n-3)}} \frac{\partial^3 q_i}{\partial \alpha_j^3} + \dots + \qquad (8)$$
$$\frac{n(n-1)\dots\left[n-(n-2)\right]}{(n-1)!} \frac{\partial q_i}{\partial \alpha_j} \frac{\partial^{(n-1)} q_i}{\partial \alpha_j^{(n-1)}} +$$
$$\left. + q_i \frac{\partial^{(n)} q_i}{\partial \alpha_j^{(n)}} \right], n = \overline{2,n},\ \text{if}\ \alpha_j \ne R_i,$$

Where n is the index corresponding to the order defined derivative and $\partial^{0} q_i/\partial \alpha_j^{0} = 0$ and is replaced by the function qi, member of the extreme terms. If the $\alpha_j = R_i$, then, obviously, the Eq. 9 will be supplemented summands $(\partial R_i/\partial \alpha_j) = 1$ which takes the form:

$$F_i^{(n)} = R_i \left[\frac{\partial^{(n)} q_i}{\partial \alpha_j^{(n)}} q_i + \frac{n}{1!} \frac{\partial^{(n-1)} q_i}{\partial \alpha_j^{(n-1)}} \frac{\partial q_i}{\partial \alpha_j} + \frac{n(n-1)}{2!} \frac{\partial^{(n-2)} q_i}{\partial \alpha^{(n-2)}} \frac{\partial^2 q_i}{\partial \alpha_j^2} + \frac{n(n-1)(n-2)}{3!} \frac{\partial^{(n-3)} q_i}{\partial \alpha_j^{(n-3)}} \frac{\partial^3 q_i}{\partial \alpha_j^3} + \ldots + \frac{n(n-1)\ldots[n-(n-2)]}{(n-1)!} \times \frac{\partial q_i}{\partial \alpha_j} \frac{\partial^{(n-1)} q_i}{\partial \alpha_j^{(n-1)}} + q_i \frac{\partial^{(n)} q_i}{\partial \alpha_j^{(n)}} \right] + n \left[\frac{\partial^{(n-1)} q_i}{\partial \alpha_j^{(n-1)}} q_i + \frac{n-1}{1!} \frac{\partial^{(n-2)} q_i}{\partial \alpha_j^{(n-2)}} \frac{\partial q_i}{\partial \alpha_j} + \frac{(n-1)(n-2)}{2!} \frac{\partial^{(n-3)} q_i}{\partial \alpha_j^{(n-3)}} \frac{\partial^2 q_i}{\partial \alpha_j^2} + \frac{(n-1)(n-2)(n-3)}{3!} \frac{\partial^{(n-4)} q_i}{\partial \alpha_j^{(n-4)}} \times \frac{\partial^3 q_i}{\partial \alpha_j^3} + \ldots + \frac{(n-1)(n-2)\ldots[n-(n-3)]}{(n-2)!} \frac{\partial q_i}{\partial \alpha_j} \frac{\partial^{(n-2)} q_i}{\partial \alpha_j^{(n-2)}} + q_i \frac{\partial^{(n-1)} q_i}{\partial \alpha_j^{(n-1)}} \right]; \ n = \overline{2,n}. \quad (9)$$

Analysis of the obtained dependences shows that the matrix of coefficients of the determined derivative is constant and does not depend on their order and from which the parameter varies, the original system of network equations. The components of the matrix is equal to unity at the desired derivatives of the nodes and $2R_i q_i$ at higher derivatives on independent paths.

Analyzing the formation of the coefficients of the higher derivatives in the system (6) and (7), it is easy to prove the validity of observations. Indeed, no matter how much we increased the order of differentiation of expressions $\partial q_i/\partial \alpha_j$ И $2R_i q_i(\partial q_i/\partial \alpha_j)$ and coefficients at higher derivatives remain unchanged.

Derived from h_L in the General case will depend on the equations of the characteristics of the source rod and its differentiation will not infringe the claims made. If h_L = const and the $\alpha_j \neq h_L$, $(\partial h_L/\partial \alpha_j) = 0$ when $h_L = f(q)$ the characteristic of the fan is easily approximated by a binomial of the form $h = H - R_в q^2$, where H = const, and $R_в$-some internal resistance of the source rod.

Therefore, the differentiation of such binomials is equivalent to differentiation of any of the components of the circuits. If the $\alpha_j = h_L$, then $(\partial h_L/\partial \alpha_j) = 1$ that will lead to free members at the same constant matrix coefficients. Thus, the system of equations for the computation of the derivatives can be written in matrix form:

$$AX^{(n)} = S^{(n)}, \quad (10)$$

Where:

A = The matrix of coefficients of the derivatives
$X^{(n)}$ = Matrix-column-defined derivatives of order n
$S^{(n)}$ = The matrix-column free members

Since, A = const, then the task of finding the numerical values of the derivatives is confined mainly to the definition of free members in the right-hand side of Eq. 10 which greatly simplifies the solution as a whole. Since, Eq. 8 and 9 fair, starting with n = 2, the solution of the problem according to the definition of derivative is divided into two phases. The first stage involves determining the derivatives of the first order solution of the system of Eq. 6.

At the second stage in the formation of the system of equations of the form Eq. 10 present a negative algorithm is easy to implement, if in the process of formation of the system of equations available members to find the Eq. 8 and 9, excluding pre-terms with derivatives of higher order which then formed the matrix-column-defined derivatives and the matrix of coefficients of the determined derivative.

The building characteristics of the interconnectedness of threads based on the decomposition of the value in the number of Macarena: Installation of underground fans as regulators working without the jumper, connected with the necessity to change the airflow in difficult-managed areas in underground mines. Regulators of this type are active, because they make more energy in total energy potential mines. The magnitude of the disturbance of the active controller is defined by the formula Eq. 3 and 4:

$$h_? = 0{,}6 \frac{\rho}{S^2} \left[\pm 2Q_?^2 \frac{S}{S_?} - (1{,}06 - 94\alpha)(2QQ_? - Q_?^2) \right] \quad (11)$$

Where:

h_e = The depression created in the development fan, Pa
Q_6 = Fan capacity, m^3/c
Q = The amount of air flowing through the formulation, m^3/c
S = Cross-section generation in the place of installation of the fan, m^2

S_6 = Cross-section of the outlet fan, m^2
ρ = Air density, kg/m^3
α = The drag coefficient formulation, Pac^2/m^2

The coincidence with the direction of flow in the formulation and at the outlet of the fan is taken from the "plus" sign at the counter with the sign "minus"; The resulting residual depression in the branches running active controller violates the uniqueness condition pressures in the respective circuits of the ventilation network and contributes to the emergence of corrective contour threads that lead to the redistribution of the costs of the air, the numerical values of which can be found from the solution of the system of equations of the form:

$$\begin{cases} \sum_{i\in S} q_i = 0; \\ \sum_{i\in L} R_i q_i^2 = \pm h_L \pm h_{B,j}, \end{cases} \quad (12)$$

Where:
h_L = The depression source of thrust which is included in the Lth path, Pa
$h_{e,j}$ = The depression active regulator without the jumper in the jth branch of the Lth path, Pa

The plus sign in front of summands in the second equation of system (12) is taken, if the direction of fan operation coincides with the direction of traversal paths, the minus sign, if not the same. The solution of system (12) allows us to estimate the effect of active control on the ventilation network in general. It should be borne in mind that the active controller without the jumper imposes some constraints on the definition of air distribution on the basis of the system of Eq. 12.

In the existing standard programs do not provide options for introduction in the calculation of this type of controllers. Therefore, to determine the desired airflow rates required in the jth branch to depression of the knob $h_{6,j}$ add depression generation h_{eb1p}, where there is a regulator.

However, in case of subsequent changes its mode of operation, such a decision must be performed on each of the next step of the regulation. To simplify the solution is to use the principle of interconnectedness of the air flow.

Let you specify the base vector $q_0 = \{q_{1,0}, q_{2,i}, . . . , q_{n,0}\}$, the components of which are the solution of the system of Eq. 13 and correspond to the distribution of air in the ventilation system at the time $h_{6,j} = 0$.

Since, the air flow in the ith generation is a function of the changing depression active regulator installed in the jth branch, laying q_i, $i = \overline{1, n}$ the number of Macarena by changing the parameter $h_{\hat{a},j}$, we obtain:

$$q_i = q_{i,0} + h_{B,j}\frac{dq_i}{dh_{B,j}} + \frac{1}{2!}h_{B,j}^2\frac{d^2q_i}{dh_{?,j}^2} + \cdots + \frac{1}{r!}h_{B,j}^r\frac{d^{(r)}q_i}{dh_{B,j}^{(r)}}; i = \overline{1,n} \quad (13)$$

Where:
$q_{i,o}$ = Air flow in the i-th managed to develop changes to the depressie in the jth control branch, m^3/c
$h_{6,j}$ = The current value of the variable depression in the jth branch, PA

Practice calculations shows that the series (13) is alternating, the convergence is ensured if the condition:

$$h_{6,j} < r\left|\frac{d^{(r-1)}q_i}{dh_{B,j}^{(r-1)}}\right| \Big/ \left|\frac{d^{(r)}q_i}{dh_{B,j}^{(r)}}\right| \quad (14)$$

To determine the unknown derivatives are included in Eq. 13 and 14, predifferentiated the system of Eq. 13 variable parameter $h_{6,j}$. Get:

$$\begin{cases} \sum_{i\in S} \frac{dq_i}{dh_{B,j}} = 0; \\ \sum_{i\in L} 2R_i q_i \frac{dq_i}{dh_{B,j}} = \pm\frac{dh_L}{dh_{B,j}} \pm 1;\ j = \overline{1,n} \end{cases} \quad (15)$$

Substituting instead of R_i и and q_i the original base values, we get a linear system of equations, solving which we find the numerical values of the first derivatives. After re-differentiation will have:

$$\begin{cases} \sum_{i\in S} \frac{d^2q_i}{dh_{B,j}^2} = 0; \\ \sum_{i\in L} 2R_i q_i \frac{d^2q_i}{dh_{B,j}^2} + \sum 2R_i\left(\frac{dq_i}{dh_{B,j}}\right)^2 = \pm\frac{d^2h_L}{dh_{B,j}^2};\ j = \overline{1,n}. \end{cases} \quad (16)$$

Similar substitutions (Eq. 16) is reduced to the line of sight relative to the second derivative. Thus, instead of $dq_i/dh_{6,j}$ are substituted for the previously found their numerical values. Continuing differentiation or by using the dependence (Eq. 8), it is possible to form the necessary equations to calculate the derivatives of any order. Acceptable accuracy is achieved when calculating three-four members of the decomposition in Eq. 13. Error in calculations, due to the fact that the number of alternating, will not exceed the absolute value of the first of dropped members.

Summarizing the above, we note that for branches with parallel connection type is characteristic of this condition $dq_i/dh_{6,j}<0$. This suggests that with increasing depression of the active controller in the jth branch of the air flow in the ith managed the development will be reduced.

For branches with a serial connection type in fair condition $dq_i/dh_{6,j}>0$. In this case, the air flow rate in the ith managed the development will increase with increasing depression of the active controller in the jth branch. If $dq_i/dh_{6,j} = 0$, then the effect on the ith branch is missing.

Thus, the proposed approach to the assessment of the impact of active regulators to modify airflow in the system of underground workings provides not only quantitative data flowing in the mine ventilation network changes, but also to assess their quality.

RESULTS AND DISCUSSION

The building characteristics of the interconnectedness of threads based on a formula of lagrange: Owing to the strict interconnection flows in the ventilation column change the aerodynamic characteristics of the passive controller in the jth branch will cause a change in flow in any element of the ventilation circuit. For paired links this dependence has the form $q=f(R_j)$.

To this function is continuous and has a continuous derivative that follows from the analysis of the system of Eq. 1, for two different values of R_j under monotonic increasing or decreasing function of air flow due to the Lagrange formula will have the equality:

$$\frac{q_i(R_{j,k}) - q_i(R_{j,H})}{R_{j,k} - R_{j,H}} = f'(R_\xi) \tag{17}$$

Where:

- $q_i(R_{j,H})$; $q_i(R_{j,k})$ = Initial and final value of the airflows in the ith branch, the corresponding initial and final values of the passive resistance of the regulator in the jth branch, m3/s
- $f'(R_\xi)$ = Derivative of a function of flow rate, corresponding to some value of resistance R is in the interval between $R_{j,i}$ and $R_{j,ê}$.

If at some point in time during the operation of the ventilation system is given an initial distribution corresponding to the initial value of resistance workings $q_i(R_{j,k})$, then changing the *j*-th resistance at a certain value the new value of the air flow can be found from the condition (Eq. 17), i.e:

$$q_i(R_{j,k}) = q_i(R_{j,H}) + f'(R_\xi)(R_{j,?} - R_{j,H}) \tag{18}$$

Thus, the Eq. 19 is the equation of the interconnectedness of ventilation flows and using it for known values $f'(R_\xi)$, where $R_{j,H}<R_\xi<R_{j,k}$ you can assess the impact of the jth element in the ith controlled air flow. At the same time, the existing technical literature is not acceptable dependencies to determine $f'(R_\xi)$. The latter are calculated in each case on the overall properties of the described research object and task conditions. Given that all changes occurring in the ventilation network of comoswaane, we can assume that the ratio of the derivatives, the underlying state of the network, to the derivatives in the interval when changing the R_j be modified in the same patterns for all branches of the original system regardless of its complexity shown in Fig. 1:

$$\frac{tg\beta_i}{tg\alpha_j} = f(R_j) \tag{19}$$

Where:

$$tg\alpha_i = \frac{dq_i}{dR_j}\Big| R_j = R_{j,H}; tg\beta_i = \frac{dq_i}{dR_j}\Big|$$

$$R_j = R_\xi, R_{j,?} < R_\xi < R_{j,k}$$

To establish patterns of change in attitude $tg\beta_i/tg\alpha_i$ depending on the change of resistance of the regulator R_j jth branch was carrying dena series of experiments, the

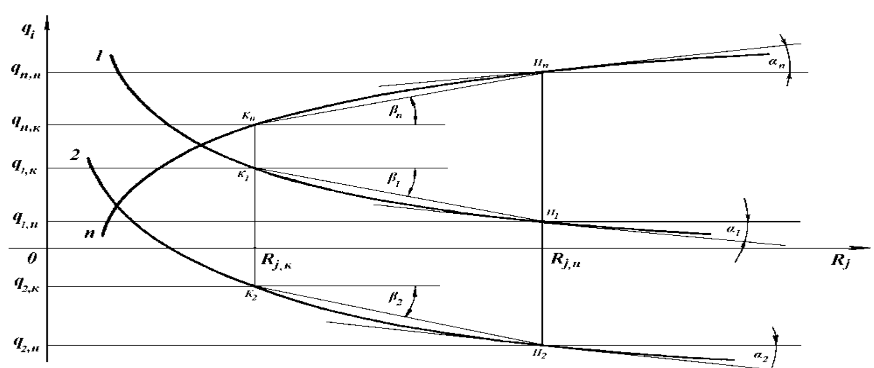

Fig. 1: The display effect of the jth regulator on the nature of changes in airflow rates in managed branches

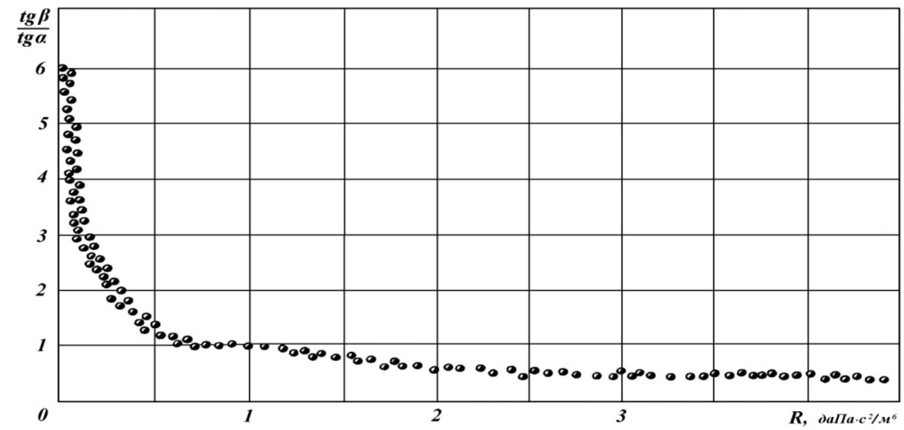

Fig. 2: The dependence of the ratio tgβ/tgα of the change of the resistance regulator

results of which are shown in Fig.2. Calculations of ventilation networks with different topological complexity and time-Noah dimension showed that the condition (Eq. 19) is best performed if the source information is the underlying distribution of the flow at a given resistance of the jth regulator R_j = 1,0 daPa.c^2/m^6. The stability of the relationship $tg\beta_i/tg\alpha_i$ increases with increasing aerodynamic resistance R_j affecting the branch. A significant scatter of points around the mean value observed at R_j<0.001 daPa.c^2/m^6.

The instability of the relationship derivatives suggests that in tensively cost changes for various branches included in the Kth node of the ventilation scheme would be significantly different from each other. This fact can be explained by the fact that for small values of R_j can disrupt the monotony of decreasing or increasing function $q_i = f(R_j)$. Indeed, for any Kth node of the estimated ventilation scheme is fair equality:

$$\sum_{i=1}^{n}\left(dq_i/dR_j\right)=0 \tag{20}$$

To the equality (Eq. 20) was performed, derivatives must be of different signs. Since changing R_j principle of proportionality for nonlinear systems fails, then the sum of the numerical values of the derivatives at the node is equal to zero only if the intensity changes of the air flow for the various branches will be different. And because with the growth of R_j because of the nonlinearity of the function $q_i = f(R_j)$ is changing and the rate of change function, it is possible that when derived from airflow rates for individual branches in a certain interval of changes of q_i can change its sign to the opposite and this is tantamount to the emergence of local maxima or minima on the curve q_i (Tarasevich, 2003). These features led to the need to limit the use according to (Eq. 18) to plot the characteristics of interconnectedness minimum value of $R_j \geq 0{,}001$ daPa.c^2/m^6.

Since $R_j \geq 0.01$ daPa.c^2/m^6 and for each subsequent increase of resistance, relations $tg\beta_i/tg\alpha_i$ with minor variations fluctuate around the average value. Increasing decreases R_j the scatter of points, which proves the correctness of the choice of initial conditions for building a functional dependency between the derivatives, on the one hand, and changing the aerodynamic impact of branches on the other. Processing of the results by the method of averages showed that the dependence $g\beta_i/tg\alpha_i$ upon the change R_j in the range from 0.1-100 daPa.c^2/m^6 well described by the Eq.:

$$\frac{tg\beta_i}{tg\alpha_i}=74,28\exp\left(-4{,}307R_j^{0.14}\right) \tag{21}$$

Because $f'(R_\xi) = tg\beta$, the Eq. 18 with Eq. 19 is converted to the form:

$$q_i=q_{i,H}+74,28\frac{dq_i}{dR_j}\left(R_j-1\right)\exp\left(-4{,}307\,R_j^{0.14}\right) \tag{22}$$

Where $q_{i,i}$ is the initial base flow in the ith generation, equal to the value R_j = 1,0 daPa.c^2/m^6. Unknown values of derivatives dq_i/dR_j are determined for the base network status in accordance with (Eq. 6). The use according to (Eq. 22) to estimate cost changes of air in the ith controlled branches effectively for coal mines, the resistance of the workings of which are quite large. As for the mines, due to the large cross-sections, having a large number of parallel branches and diagonal elements, this model has openings are small size and ranges from 0.00001-0.01 daPa.c^2/m^6. Therefore, the use according to (Eq. 22) for such conditions is

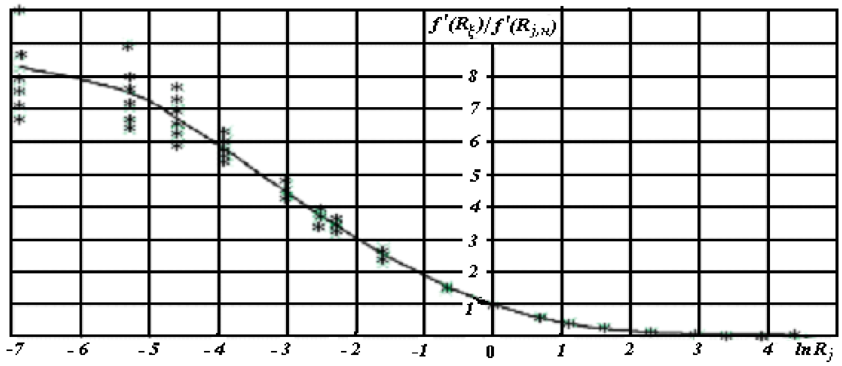

Fig. 3: The logarithmic dependence of the ratio $f'(R_\xi)/f'(R_{j,H})$ of the change of the resistance regulator R_j

impractical. As for the basic costs of air $tg\alpha_i$ = const, from Fig. 2 that as the asymptotic approximation function to the vertical axis increases dramatically the magnitude of the relationship $tg\beta_i/tg\alpha_i$ which leads into the process-behold the use of Eq. 22 to errors in the calculations at small values R_j.

On the graph of Fig. 3 presents the results of changing the value $f'(R_\xi)/f'(R_{\xi,H})$ of the resistance regulator R_j in the range from 0.001-3 daPa.c^2/m^6 (Levitsky *et al*., 2012). The x-axis is the natural logarithm of the resistance values of the regulator $R_{4,8}$. From this it follows that the ratio of the derivative $f'(R_\xi)$ to the derivative of the base point $f'(R_{j,H})$ corresponding to the state of the network at $R_{j,i}$ = 1.0 daPa.c^2/m^6, $i=\overline{1,n}$ changes in the process of amending the R_j one and the same law for all branches of the ventilation system that allows, and in the case of small values of the resistance changes of regulators to obtain the appropriate dependencies to assess the impact of the management branch for controlled ventilation flows.

For the interpolation of the experimental data was applied method is the most ordinary least squares (Tarasevich, 2003). As the approximation function was chosen as a polynomial of the fourth degree, allowing you to desribe dependence relations $f'(R_\xi)/f'(R_{j,H})$ from changes in the resistance of the regulator. Because of the lack of approximation polynomial is the discrepancy with the experimental data at the ends of the range (in this case, $R_{4,8}$>50 daPa.c^2/m^6), as well as by dependency relations $f'(R_\xi)/f'(R_{j,H})$ from changes in the resistance of the regulator R_j is close to the line-Noah on the interval $10 \le R_j < 100$ daPa.c^2/m^6, the adjustment range of the regulator was adopted $0.001 < R_j < 1$ daPa.c^2/m^6. Finally, dependence which is described by Eq. 23:

$$f'(R_\xi)/f'(R_{j,H}) = (1 - 0{,}714\ln R_j + 0.163(\ln R_j)^2 - (6.56\times10^{-4})\cdot(\ln R_j)^3 - (3.47\times10^{-3})(\ln R_j)^4 \quad (23)$$

Becausef$_\cdot$(R_ξ) = $tg\beta_i$, the eq. 18 with Eq. 19 is converted to the VI-control:

$$q_i = q_{i,?} + [1 - 0{,}714\ln R_j + 0.163(\ln R_j)^2 - (6.56\times10^{-4})\cdot(\ln R_j)^3 - (3.47\times10^{-3})\cdot(\ln R_j)^4]\cdot\frac{dq_i}{dR_j}\cdot(R_j - 1) \quad (24)$$

The obtained dependence (Eq. 24) allows to determine the value of the new air flow in any of the ith branch of the design scheme when changing the aerodynamic resistance of the regulator R_j in a given range without the need for solving multidimensional nonlinear system of equations. Giving the aerodynamic resistance of the regulator R_j sufficiently small increment, the process of differentiation and calculations basic derivatives can be performed with sufficient practical accuracy by the equation:

$$\frac{dq_i}{dR_j} \cong \frac{q_{i,H} - q_{i,k}}{R_{j,H} - R_{i,k}} \quad (25)$$

Where:

$q_{i,i}$ = Base flow in the ith generation at $R_{j,i}$ = 1.0 daPa.c^2/m^6, m^3/c;

$q_{i,k}$ = Air flow in the ith generation if $R_{j,k}$ = 0.95 daPa.c^2/m^6, m^3/c

Comparative calculations performed for different ventilation systems, showed that the approximating Eq. 22 and 24 with suffi-Noah to practice precision characterizes the coupling of the air flow in the mine ventilation network in a wide range of changes in aerodynamic drag affecting the branch. Their use increases the efficiency assessment of air distribution in a complex ventilation systems, eliminating the need for each step of the regulation to solve multidimensional nonlinear system of equations. This should draw attention to the fact that derivatives $dq_i/dR_j,\ j=\overline{1,p}$ are the terms of a qualitative assessment of changes occurring in the ventilation system under the influence of the jth controller. They mark easily separate branches, in which the air flow will decrease or increase. If $dq_i/dR_j>0$, in such branches with increasing Rj, will increase and the air flow that characterizes the conditional parallel relationship management j-th branch with a controlled air flow in the i-th branch.

When $dq_i/dR_j<0$ the result will be the opposite, that characterizes the conditional serial communication controller with a controlled air flow. In accordance with the Lagrange formula for functions of several variables the equation of continuity (Eq. 22) is easily generalized to the simultaneous change in any number of aerodynamic parameters in the ventilation network and takes the form:

$$q_i = q_{i,?} + \sum_{j=1}^{p} 74,28\frac{dq_i}{dR_j}\left(R_j - 1\right)\exp\left(-4,307R_j^{0,14}\right).\quad (26)$$

Similarly, according to Eq. 23:

$$\begin{aligned} q_i = q_{i,?} + \sum_{j=1}^{p}[1 - 0,714\ln R_j + \\ 0.163(\ln R_j)^2 - (6.56\times10^{-4})\cdot(\ln R_j)^3 - \\ (3.47\times10^{-3})\cdot(\ln R_j)^4]\cdot\frac{dq_i}{dR_j}\cdot(R_j - 1) \end{aligned}\quad (27)$$

The algorithm is based on the calculation of dependencies (Eq. 26) and (Eq. 27) reduces to follow properly. First calculated the base distribution $fq_{i,H}$, i = 1,2...,n or the condition when all variables R_j = 1,0 daPa.c^2/m^6. After determining the basic state are consistently derived dq_i/dR_j for all variables R_j, = 1, 2, . . . , p.

CONCLUSION

Carried out researches have shown, that on the basis of the application of Taylor series, MacLaren and formulas Lagrangian can be constructed functional dependency to evaluate the impact of changing the aerodynamic parameters of one or more simultaneously operating the controls on the distribution of air flows in complex ventilation networks. Installed a new property of the ventilation system which ensures that the numerical characteristics of the relations derived in managed threads when changing at a given period of operation of the controller in the control branches to the derivatives of the same threads corresponding to the base state of the ventilation network can be represented as exponential (Eq. 22) or logarithmic (Eq. 24) dependencies. The presented approach to the analysis of complex ventilation networks allows you to not only give a qualitative assessment of the perturbing effects of passive or active regulators to change airflow rates in managed branches, but also a quantitative evaluation by determining the change in air flow in any managed element's ventilation system when changing the aerodynamic characteristics of the individual regulators or groups included in the control system ventilation.

REFERENCES

Abramov, F.A., R.B. Chan and C.I. Potemkin, 1978. Calculation of Ventilation Networks Mines. Nedra Publ., Moscow, Russia, Pages: 232.

Choi, S. and E.I. Horns, 1965. Basic Theory of Ventilation Networks. Nauka Publ., Almaty, Kazakhstan, Pages: 283.

Levitsky, 2003. Aeromechanics Ventilation Flows. Karstu Publ., Karaganda, Kazakhstan, Pages: 228..

Levitsky, J. and A.C. Sokolov, 2011. Application of the theorem of lagrange to the analysis of complex ventilation systems. Proc. Karaganda State Tech. Univ., 42: 50-54.

Levitsky, J., J.K. Amanzholov and A.D. Nurgaliyev, 2012. Active users of tor and its impact on the distribution of air flow in complex ventilation network. Saf. Ind., 5: 50-53.

Tarasevich, Y.Y., 2003. Numerical Methods for Mathcad. ASPU, Astrakhan, Russia, Pages: 70.