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COMPUTER DESIGN OF MINE PNEUMATIC NETWORKS

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SUMMARY
More precise method for mine pneumatic networks (MPN) design, served as verbal algorithm for creation a program in MATLAB environment is developed. Among great number of variants of main MPN properties an optimal one in regard of capital and operational costs can be defined by applying the method. Computer program can give information about main MNP properties in mine development process and also in its life cycle stages. Main MPN parameters' optimization at the design stage increase its operational effectiveness.

The following main requirements for Mine Pneumatic Networks (MPN) should be taken into account at design stage:

- To supply needed compressed air amounts to consumptions with predefined pressure and with minimal losses;
- Minimal capital costs;
- Minimal operational costs;
- Parallel to mine development to expand pneumatic system without its' economic parameters reduction.

Minimal capital costs can be achieved by usage of as little as possible pipeline diameter while minimal operational costs (minimal pressure loss) are less if tubes are greater. Talking about the same pipeline we have two opposite requirements which lead to great differences and discrepancies in MPN design.

Variations in consumers' number, in compressed air amounts supply, total distribution network length expansion and complication in its structure accompany each mine development. In the contrary to this reality, at design stage such networks are assumed to be stationary in time, with maximal consumers, compressed air amounts and pipelines' length. Such network design is not rational, exact compressed air amounts for different sections are not known, as well as total costs for different stages of its development and operation. These design MPN methods (Garbus, 1961; Smorodni, 1980; Цейтлин, Мурзин, 1985; Jankov, 1980) apply empirical formulae, family of curves and narrow diapasons of compressed air velocity variations.

The method developed and presented in this paper tries to overcome the above written problems by taking into account the most favorable compressed air velocity in pipeline under optimal capital and operational costs. At each stage of network development information for its main parameters can be obtained. The method developed serve as a basic algorithm for computer program in MATLAB environment. Data input is performed in matrix way in accordance with pneumatic network topology.

The essence of method comprises of calculation of inside pipeline diameters starting from the most distant section towards compressor station. It is assumed that pressure is equal elsewhere to the greatest nominal consumption pressure. Compressed air discharge at each supply point is evaluated, i.e. at the compressed station exit. This is performed by application of known analytical methods (Degtjarev, 1987; Smorodni, 1980; Цейтлин, Мурзин, 1985). Then calculation of inside diameters and pressure losses for each network section takes place.

Pneumatic network dimensioning is done at two basic stages. The first one is to calculate great number of variants for the highway pipeline and to choose the optimal (with minimal total capital and operational costs keeping velocity into desired limits). The second one includes calculation of subsidiary branches' diameters and total economic parameters.

Highway sections' inside diameters are calculated under the expression for air discharge of compressible fluid through a given surface:

$$F.u = V_y \frac{\rho_0}{\rho_{cp}}, \qquad (1)$$

where:

F is pipeline cross section area for dimensioning part, m^2;
u – compressed air velocity in pipeline, m/s;
V_y – air discharge through section, m^3/s;
ρ_0 – atmospheric air density, kg/m^3. For normal conditions it is set to be ρ_0 = 1,2 kg/m^3 (Smorodni 1980).
ρ_{cp} – compressed air average density in the section, kg/m^3.

The most favorable values for air velocity in mine pneumatic networks design methods (Цейтлин, Мурзин, 1985; Jankov, 1980) are in the range 6 - 10 m/s. Long term research

(Smorodni, 1980) in Leningrad mine institute show that it can be broaden to 4 - 12 m/s.

Compressed air average density in sections is calculated under expression:

$$\rho_{cp} = \frac{p_{cp}}{R.T_{cp}},\ kg/m^3, \qquad (2)$$

where:

p_{cp} is average pressure in pipeline, equals to mean arithmetic value between pressure at the two sides of pipeline section, Pa;

R – gas constant. Equals to 287 J/kgK;

T_{cp} – average temperature of compressed air in pipeline, K.

Writing expression for cross section area by inside diameter of section pipeline D_y and substituting values for ρ_0, u, R and ρ_{cp} in (2) the following formula for inside diameter is obtained:

$$D_y = \sqrt{\frac{438{,}5 V_y T_{cp}}{(4 \div 12) p_{cp}}},\ m. \qquad (3)$$

Pressure losses in pipeline are calculated under Darsy-Weisbah formula (Цейтлин, Мурзин, 1985):

$$\Delta p_y = \frac{5{,}62.M_y^2.T_{cp}.L_y}{D_{cp}^{5,3}.p_{cp}},\ Pa, \qquad (4)$$

where:

M_y is mass discharge of compressed air through pipeline section, kg/s.

$$M_y = \rho_0.V_y,\ kg/s, \qquad (5)$$

L_y – section length, m.

$$L_y = 1{,}15\ell,\ m, \qquad (6)$$

ℓ - design length of section, m.

The length ℓ of each section increases with 15 % in order to compensate pipeline inclination and length losses due to assembling work.

Data consisting of V_y, M_y, Δp, p_{cp} and D_y for each variant for highway pipeline of pneumatic network is obtained. They are utilized to calculate total volumetric flow rate $V_{пм}$ through pneumatic network and pressure loss at compressor station exits $p_{кс}$.

Arbitrary great number of variants for highway pipeline can be generated. Taking 0,1 m/s step for calculation of reasonable velocity range 81 variants of pipelines for particular pneumatic farm are obtained. All variants are dimensioned for normal work of pneumatic consumption, but not all of them are economically enough in regard of total capital and operational costs.

Optimal variant for which pneumatic network will show favorable values of D_y and Δp is defined via comparison of values of diameters and pressure losses for equal velocities of compressed air. Program output can be either numerical or graphical. For each variant average diameter D_{cp} and total pressure loss $\sum\Delta p$ are calculated. Diagrams of D_{cp} = f(u) and $\sum\Delta p$ = f(u), shown on figure 1, can be built upon these parameters.

Table 1 shows main input and output data in cost optimization of highway pipeline procedures.

Table 1

Sec tion №	V_y, m^3/s	M_y, kg/s	Δp_y, MPa	p_{cp}, MPa	D_y, m	D_cp, m $\sum\Delta p$, Mpa $p_{кс}$, MPa
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Cross section point of curves D_{cp} and $\sum\Delta p$ define optimal values of average diameter, pressure losses and compressed air velocity, i.e. optimal variant for highway pipeline, namely D_{cp_0}, $\sum\Delta p_0$ and u_0. This variant is obtained for exactly defined air velocity while using for this process inside diameters and total losses. In order to obtain standard inside pipeline diameters under optimal losses pre-calculation of highway pipeline is required for optimal air velocity ($u=u_0$).

Main pneumatic network parameters' optimization is performed only for dimensioned highway pipeline because during its construction main part of capital costs are spent, the whole amount of compressed air passes through and great pressure losses are counted there.

The second stage of mine pneumatic network design is inside diameter of subsidiary network evaluation under known pressure losses. This is done by formula (4) which is solved for inside diameter D_y. All data is given in table view for sections of subsidiary branches.

Computer program gives information for all pneumatic network pipelines' diameters, volumetric yield of compressed air for any section, parts of network and for the whole network. It can calculate costs and diameters when number of consumers and length change.

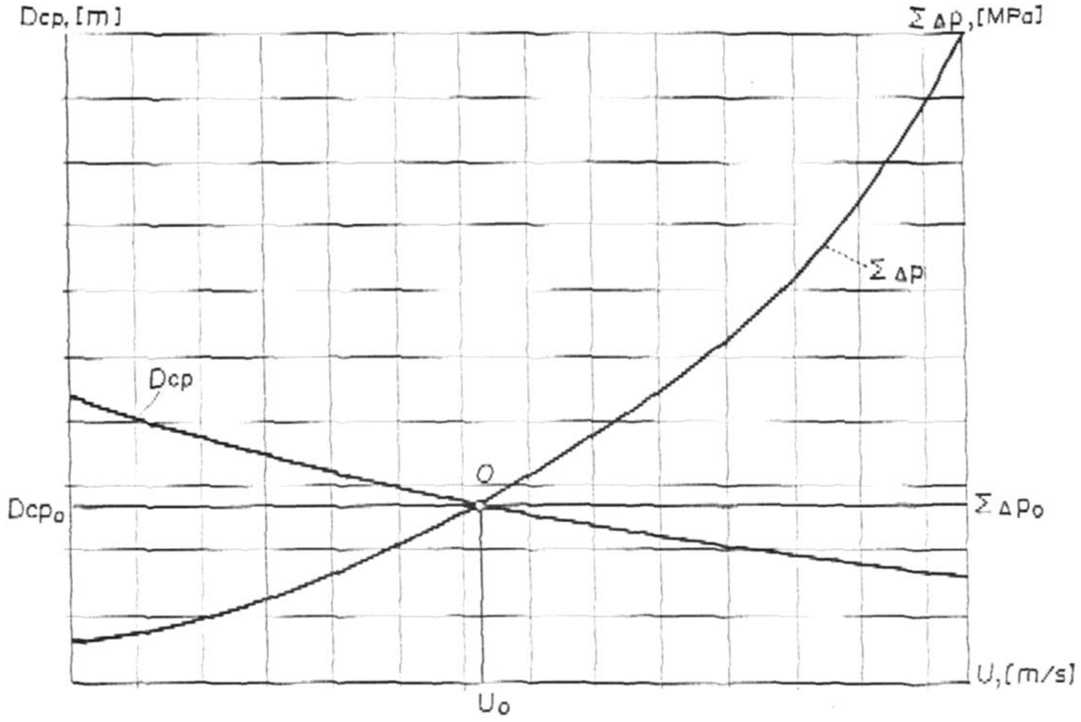

Figure 1.

CONCLUSION

1. Developed more precise method for mine pneumatic networks design served as verbal algorithm for computer program in MATLAB environment creation. It includes expansion of appropriate velocity range.
2. Method enables to choose optimal variant among great number of variants for main parameters of highway pipeline. Optimization is performed in regard of capital and operational costs.
3. Computer program cane give information about main pneumatic network parameters not only for static situation but in dynamic environment for variations in consumption number, length and stages of its construction during mine life cycle.
4. Computer program application decreases design time and increases its effectiveness.

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