UPDATING THE AERODYNAMIC RESISTANCE FOR SUBSURFACE VENTILATION

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ABSTRACT

For the safety works in the mines good ventilation is one of the main requirements. For miners' performance, the subsurface ventilation creates healthier and more hygienic conditions. Mine ventilation has always belonged to the field of mining. Moreover, nowadays the mining operations progress to greater depths, shafts are deepened and the under-level mining space develops. This brings an increase in the temperature of rocks, mine air gets heated due to the technologies used and, thus, it is necessary to pay constant attention to mine ventilation. The knowledge of aerodynamic resistance becomes crucial for the good ventilation and ventilation planning. The article describes updating and complementing the aerodynamic resistance of the powered coalface supports, dam and wind structures and auxiliary ventilation components.

Keywords: subsurface ventilation, aerodynamic resistance, ventilation components, velocity

1 INTRODUCTION

Proper ventilation is one of the basic conditions for work safety in mines. Mine ventilation creates not only the positive health and hygiene conditions in the mines, but also significantly affects the performance of the miners and their safety while performing the mining occupation.

As parts of the amendment of the standardization directive on mine ventilation, it was necessary to do the following:

1. Update and complement the aerodynamic resistance of the powered coalface supports.
2. Update and complement the aerodynamic resistance of dam and wind structures.
3. Update and complement the aerodynamic resistance of auxiliary ventilation components.

2 AERODYNAMIC RESISTANCE OF THE COALFACE SUPPORTS

The determination of aerodynamic resistance of coalface supports comprises two steps:

1. Measuring the necessary quantities of ventilation in coalfaces with powered support.
2. Determination of the required mathematical parameters for each type of the powered supports, especially:
    a) the light, operational and real working section of the workspace,
    b) the volume of air flow through the coalface space,
    c) aerodynamic resistance of the transition heading – coalface, further of the specific aerodynamic resistance of the coalface and finally the overall aerodynamic resistance of the coalface [1, 2].

Velocity profiles and maintained areas of a coalface space

Two quantities are measured:

1. The pressure gradients at the coalface and at the transition heading – coalface.
2. Air velocities in the transverse profile of the coalface workspace in order to create velocity profiles (Figure 1), as well as air velocities in the adjacent coalface heading in order to calculate volumetric flows of air in coalfaces (to measure the total flow volume before a part of mine air separates into coalface caving space) [3].

Several steps for velocity profiles:

- Determine the real working section of the workspace,
- Create the sites for air velocity measurements,
- Create the velocity profiles in the maintained areas of a coalface space.

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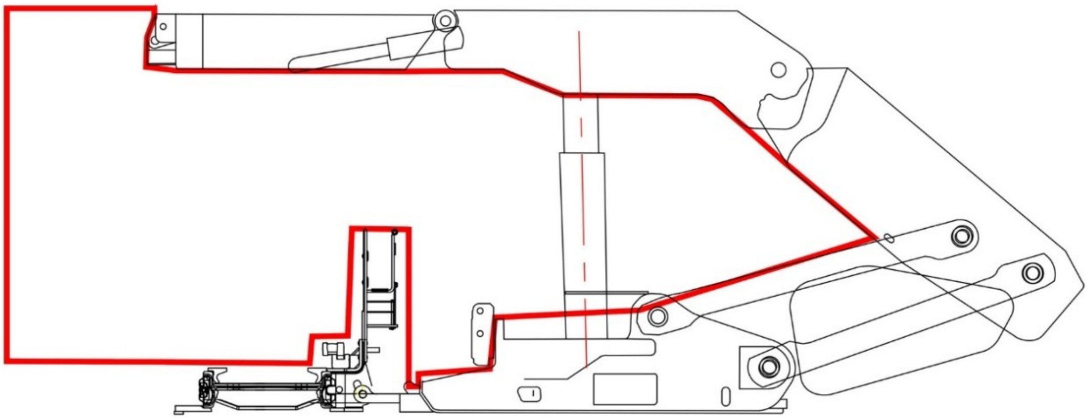

Figure 1 The real working section of the workspace

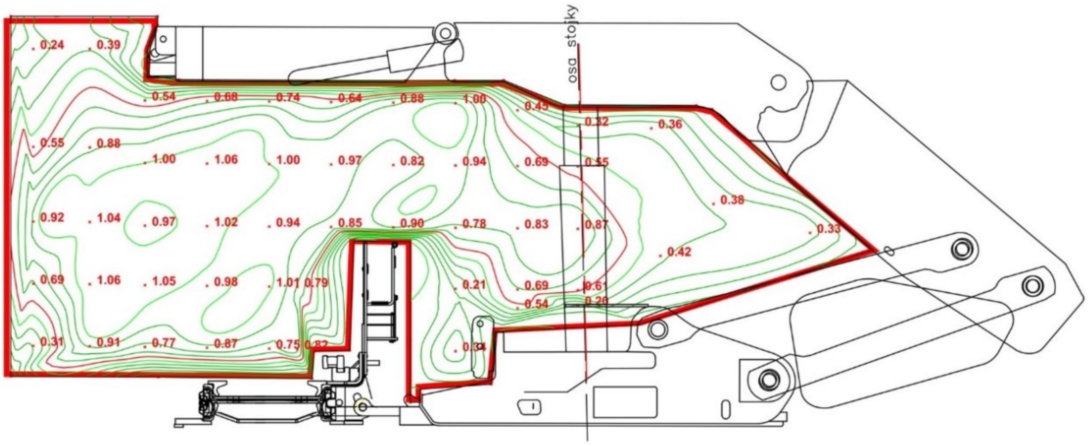

Figure 2 Speed profile of the measured velocity of air in a coalface with MEOS 25/56 support

- Measure the pressure gradients at the coalface, minimal in the 30 m length of the coal face [4]
- Determine the workspace using AutoCAD or using the equation of workspaces at a coalface [5]
- Or choose a functional equation of workspaces at a coalface

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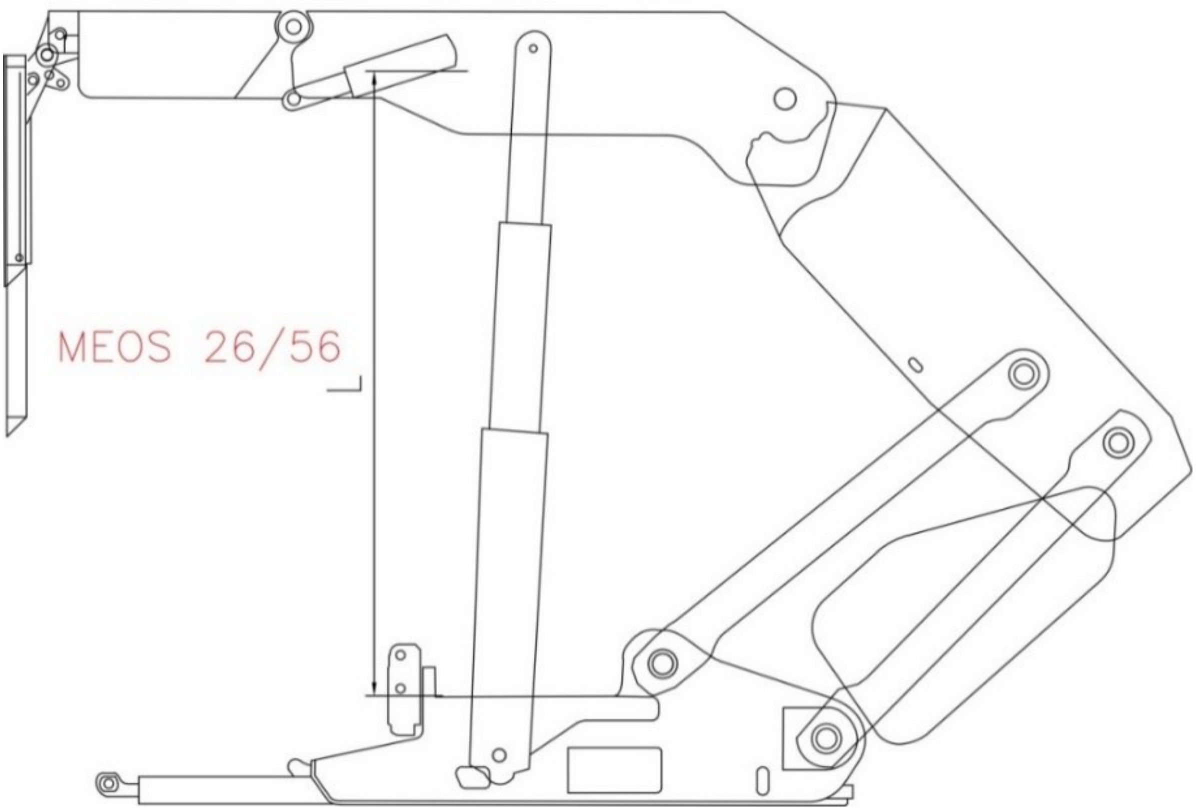

Figure 3 Characteristic dimension L for MEOS 26/56 support

Table 1 Functional equation of workspaces at a coalface for the individual support types

Support type	S [m^2]	S_0 [m^2]	m_d [m]
FAZOS 12/28	$S = 3.12 \cdot m_0 - 1.75$	$S_0 = 3.12 \cdot m_d - 2.35$	$m_d = L + 0.3$
MEOS 26/56	$S = 5.81 \cdot m_0 - 5.9$	$S_0 = 5.81 \cdot m_d - 6.9$	$m_d = L + 1.0$
DBT 2800/6000	$S = 4.53 \cdot m_0 - 3.24$	$S_0 = 4.53 \cdot m_d - 4.24$	$m_d = L + 1.4$

S - the area of the workspace light section,
S_0 - the area of the workspace operating section,
m_d - mined thickness,
L - characteristic dimension (Figure 3) to determine m_0 .

Volumetric flow through a maintained coalface space

$$Q_{v0} = 0.896 \cdot Q_{v3}^{0,9936} \qquad [m^3 \cdot s^{-1}] \qquad (1)$$

$$Q_{v3} = S \cdot v_2 \qquad [m^3 \cdot s^{-1}] \qquad (2)$$

where
Q_{v3}- the calculated volumetric flow through the area at a flow rate v_2.[m^3.s^{-1}].
v_2 - the average (mean) flow velocity in the coalface operation space [m.s^{-1}].

Table 2 Measured values for new types of supports

Support type	m_0 [m]	l [m]	Q_v through a coalface [m^3.s^{-1}]	Δp (beginning heading-coalface) [Pa]	Δp (upcast heading-coalface) [Pa]	Δp (coalface) [Pa]
FAZOS 12/28.	2.1	105	9.1	2.4	-	4.8
MEOS 26/56	3.5	32	14.1	2.4	4.8	1.6
DBT 2800/6000	4.9	74	23.0	8.0	9.6	5.6

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Table 3 Evaluation of the resistance of the measured values

Support type	m_0 [m]	R (beginning heading-coalface) [kg.m^{-7}]	R (upcast heading-coalface) [kg.m^{-7}]	R_{100} (coalface) [kg.m^{-7}]
FAZOS 12/28.	2.1	0.02898	-	0.05520
MEOS 26/56	3.5	0.01207	0.02414	0.02515
DBT 2800/6000	4.9	0.01512	0.01815	0.01431

From the pressure gradients at the coalface [6] volumetric flow through a maintained coalface space by using Atkinson´s law we can calculate the aerodynamic resistance of the measured part of coalface and convert to aerodynamic resistance of 100m coalface. Next, we can put the value in a graph with other measured resistances. Using regression we get the equation to determine specific aerodynamic coalface resistance [7].

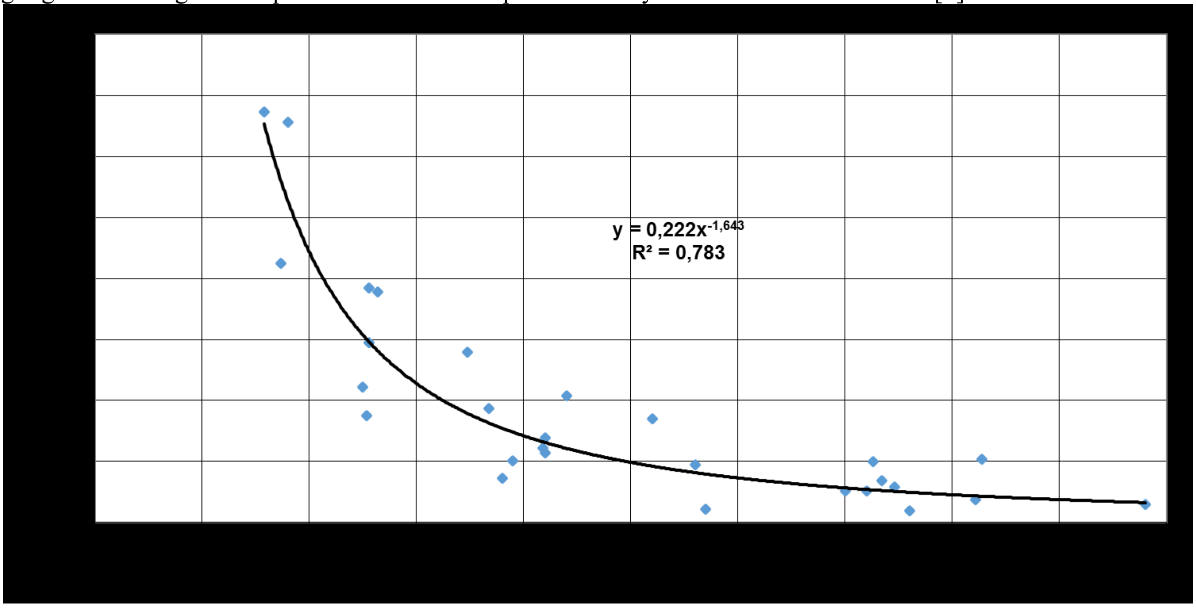

Figure 4 The regression curve of aerodynamic resistance

The shape of the functional equation to determine the specific resistance of the coalface R_{100} is for: air mass density ρ 1.2 kg.m^{-3}

$$R_{100} = 0.205 \cdot m_d^{-1,643} \qquad [\text{kg.m}^{-7}]\ (3)$$

air mass density ρ 1.3 $\text{kg} \cdot \text{m}^{-3}$

$$R_{100} = 0.222 \cdot m_d^{-1.643} \qquad [\text{kg.m}^{-7}]\ (4)$$

Table 4 Specific aerodynamic coalface resistance

Seam thickness	Specific aerodynamic resistance R_{100}[kg.m^{-7}]		Seam thickness	Specific aerodynamic resistance R_{100}[kg.m^{-7}]	
[m]	ρ = 1.2 kg.m^{-3}	ρ = 1.3 kg.m^{-3}	[m]	ρ = 1.2 kg.m^{-3}	ρ = 1.3 kg.m^{-3}
2.5	0.04549	0.04926	**5.5**	0.01245	0.01349
2.6	0.04265	0.04619	**5.6**	0.01209	0.01309
2.7	0.04009	0.04341	**5.7**	0.01174	0.01272
2.8	0.03776	0.04090	**5.8**	0.01141	0.01236
2.9	0.03565	0.03860	**5.9**	0.01110	0.01202
3.0	0.03372	0.03651	**6.0**	0.01080	0.01169

For measurements in the profile we used a vane anemometr Testovent 4000. The low velocities were measurred by C-Meter.

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Figure 5 Anemometr Testovent 4000

3 AERODYNAMIC RESISTANCES OF DAM AND VENTILATION FACILITIES

Aerodynamic resistance of any ventilation device or long mine workings was determined using the arithmetic average of a series of aerodynamic resistances detected. Ten measurements were made for each facility or workings [8].

Ventilation facilities and profiles were selected based on the current conditions to carry out measurements of the particular facility in situ. One of the prerequisites for the selection was, if possible, a tight position of the ventilation facility; in the case of long mine workings, it was important that there were no obstacles increasing the aerodynamic resistance and that the profile was not pressed. Following the already known values of ventilation facilities, a table of new types of ventilation facilities was elaborated based on new findings, with a possible range of aerodynamic drag, important primarily for the purpose of designing a ventilation network [9].

1. Dam door with conveyor passage through the insulating installation (DD+CPII).
2. Dam door with a flap for a suspension groove (DD with a flap for SG).
3. Pass through the insulating installation (PII).
4. Ventilation door 1-wing (VD 1w).
5. Ventilation door 2-wing (VD 2w).

Table 5 The example of measured dam

Measured and calculated value						
Barometric pressure	**Pa**	100 900				
Dry temperature	**°C**	26.3				
Wet temperature	**°C**	22.0				
Humidity	**%**	68.9				
Saturated vapour pressure	**Pa**	3 422				
Density of air	**kg.m^{-3}**	1.162				
Determination R	**List of measurements**	Δp	S	v	Q_v	R
		Pa	m^2	m.s^{-1}	m^3.s^{-1}	kg.m^{-7}
	1	125	16.5	0.23	3.9	8.43313
	2	127	16.5	0.23	3.9	8.56806
	3	161	16.5	0.24	4.0	9.89686
	4	689	16.5	0.38	6.2	17.73285
	5	698	16.5	0.39	6.4	16.952606
	6	140	16.5	0.24	4.0	8.750000
	7	142	16.5	0.23	3.8	9.833795
	8	130	16.5	0.24	4.0	7.991257
	9	590	16.5	0.34	5.6	18.813776
	10	620	16.5	0.39	6.4	15.058189

Table 6 Aerodynamic resistance of ventilation facilities

Facility type	equipment	Measured pcs	R [kg.m^{-7}] at ϱ 1.2		R [kg.m-7] at ϱ 1.3	
			from	to	from	to
Dam	DD+CPII	4	0.81487	1.13652	0.597364853	1.221756469
	DD with a flap for SG	4	2.78892	12.60001	2.998090044	13.54501051
	PII	2	5.12238	6733.3833	5.506563454	7238.387048
Ventilation door	VD 1w. screen brattice	2	29.12391	79.97671	31.30820023	85.97496155
	VD 2w. wall	2	353.99692	573.56849	380.5466904	616.5861277

4 AERODYNAMIC RESISTANCE OF AUXILIARY VENTILATION COMPONENTS

The next important parameter for ventilation planning are aerodynamic resistance of auxiliary ventilation components. We used special laboratory conditions to measure a flexible duct with different diameters and shaped pieces with different angles. All the components were measured in real conditions in forcing and combined system. [10]

Auxiliary ventilation components and used ventilation system:

Forcing system

- overpressure unsupported duct Φ 800. 1000 and 1200 mm,
- bend 90° a 30° and universal supported duct Φ 800 and 1000 mm.

Combined system (forcing and sucking system)

- universal supported duct Φ 800 and 1000 mm with distance of steel rings 50 and 150 mm.

Figure 6 Overpressure unsupported duct with 30° bend

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Figure 7 Distance piece for measuring

Figure 8 Measuring station with micromanometers and Pitot tube

In every system we measured the following parameters:

- dynamic pressure in cross section of a duct p_d [Pa]
- static pressure in distance peace for measuring p_s [Pa]
- temperature of air in the duct t [°C]
- temperature outside t [°C]
- barometric pressure p_0 [kPa]

Volume flow

$$Qv = S \cdot v$$ [m³.s⁻¹] [5]

S - cross section of a duct [m²]
v - velocity in measure point [m.s⁻¹]

Velocity in measure point

$$v = \sqrt{\frac{2.pd}{\rho}}$$ [m.s⁻¹] [6]

pd – dynamic pressure in measure point [Pa]
ρ – density of air in measure point [kg.m⁻³]

Aerodynamic resistance of the measure section R:

$$R = \frac{\Delta p_s}{Q_V^2}$$ [kg.m⁻⁷] [7]

Δ ps - difference of static pressure [Pa]
For density ρ=1.2 [kg.m⁻³]
$p_{st1.2}$ - static pressure at the beginning and at the end of the distance piece [Pa]
Qv - volume flow [m³.s⁻¹]

Table 6 Aerodynamic resistance of auxiliary ventilation components

Type of auxiliary ventilation component	**Specific aerodynamic resistance (for 1 m of duct) r** [kg.m⁻⁷]
Overpressure unsupported flexible duct TESECO ϕ 800 mm	0.03637
Overpressure unsupported flexible duct TESECO ϕ 1 000 mm	0.01551
Overpressure unsupported flexible duct TESECO ϕ 1 200 mm	0.00652
Universal supported duct TESECO with distance of steel rings 50 mm, ϕ 800 mm, forcing system	0.08110
Universal supported duct TESECO with distance of steel rings 150 mm, ϕ 800 mm, forcing system	0.06613
Universal supported duct TESECO with distance of steel rings 50 mm, ϕ 800 mm, sucking system	0.05270
Universal supported duct TESECO with distance of steel rings 150 mm, ϕ 800 mm, sucking system	0.05890
Universal supported duct TESECO with distance of steel rings 50 mm, ϕ 1000 mm, sucking system	0.02296
Universal supported duct TESECO with distance of steel rings 150 mm, ϕ 1000 mm, sucking system	0.01782
Universal supported duct TESECO with distance of steel rings 50 mm, ϕ 1000 mm, forcing system	0.02262
Universal supported duct TESECO with distance of steel rings 150 mm, ϕ 1000 mm, forcing system	0.01502
Universal supported duct TESECO with distance of steel rings 150 mm, ϕ 800 mm, with 30° bend, forcing system	3.3889
Universal supported duct TESECO with distance of steel rings 150 mm, ϕ 800 mm, with 30° bend, forcing system	1.3934

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Universal supported duct TESECO with distance of steel rings 150 mm, ϕ 1000 mm, with 30° bend, forcing system	1.5966
Universal supported duct TESECO with distance of steel rings 150 mm, ϕ 1000 mm, with 90° bend, forcing system	0.2967

5 CONCLUSIONS

In the first phase of updating the aerodynamic resistance for subsurface ventilation it was necessary to study the existing materials used for the particular calculations of mine ventilation and add the necessary parameters of aerodynamic props of the new powered supports for the needs of ventilation designers or supervisors.

In this context, the measurement and evaluation of ventilation parameters for new types of technology used at the OKD mines was carried out, and equations for calculation of aerodynamic coalface support resistance and transitions coalface – heading depending on the mined seam thickness were created. Likewise, with the development of computer technology, it was necessary to measure new used types of dam and ventilation facilities and to determine the minimum and maximum values of resistance of these facilities. In the last part of this branch, new types of used auxiliary fans and fittings for separate ventilation were measured, and aerodynamic resistances needed for designing ventilation were standardized again. The last type of aerodynamic resistance can be used not only for subsurface ventilation but for underground ventilation using tunnelling.

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