POSSIBILITIES OF UTILIZATION OF SIT PROGRAM FOR OPTIMIZATION OF VENTILATION IN AREA ENDANGERED BY SPONTANEOUS COMBUSTION

MOŽNOSTI VYUŽITÍ PROGRAMU SIT PRO OPTIMALIZACI VĚTRÁNÍ V OBLASTI OHROŽENÉ SAMOVZNÍCENÍM

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Abstrakt

V tomto článku je názorně na konkrétním praktickém případě předvedena možnost využití programu SIT, ve verzi 2.39, pro optimalizaci pomocí regulace ve větrní síti vedoucí k omezení průtahů závalovými prostory popř. obecně horninovým masívem v oblastech ohrožených samovznícením. Před samotným započetím optimalizace rozložení tlakových spádů je potřebné důkladně analyzovat výchozí stav. Znamená to, že je potřeba z hlediska stavby horninového masívu a jeho porušenosti geologickými procesy a předchozí hornickou činností vytipovat možné komunikace důlního ovzduší mezi jednotlivými důlními díly, které při prvním pohledu na mapovou dokumentaci větrání nejsou mnohdy zcela exaktně patrné.

Abstract

This article clearly demonstrates on a specific practical example the possibility of using the SIT program, version 2.39, for optimization of a mine ventilation network using control to reduce drafts through caved areas, or in general through rock mass in areas threatened by spontaneous combustion. Before starting to optimize the distribution of pressure gradient it is necessary to analyze the starting position deeply. It means that in terms of the construction of rock mass and its disruption by geological processes and previous mine activities, it is necessary to identify possible mine airways between individual mine workings, which at first glance at the map documentation of mine ventilation are not quite exactly evident.

Key words: Mine ventilation, spontaneous combustion, pressure gradient.

1 INTRODUCTION

This paper was processed when solving the GA CR project 105/06/1201 - *Systematic method of analysis of safety risks associated with the output of methane from underground,* under the financial support of the Grant Agency of the Czech republic (GA CR), and when solving the VaV *55/07* project *Safety work and operation in mining activities and selected activities performed by mining methods*.

To illustrate the optimization using control in a ventilation network the situation was chosen from the 4th block of the Jan-Karel Mine locality, ČSA Mine in Karviná from the year 2004.

The 4th block of the ČSA Mine was chosen to model individual variants of the configuration of ventilation network quite purposely. In 2004, in this mining block mining activities were performed simultaneously in the 37th seam consisting in mining the face No. 14791 and in the 39th seam consisting in opening out the face No. 14936 (Fig. 1). Both seams are in this area prone to spontaneous combustion, which in the past in some cases passed over to a fully developed stage.

In this context it is important to analyze the distribution of pressure gradients in the ventilation network and determine measures to minimize them in the airways. It is indeed possible to validate the method for individual variants by practical measurements at the mine, but it is very difficult and in particular not too flexible and operational. Therefore, the use of the following procedure is infinitely preferable. In this case, first of all the depression conditions of initial state are found out, subsequently by mathematical modelling the best option is determined to eliminate drafts, which is then implemented at mine and the result is again verified by measurements.

2 ANALYSIS OF INITIAL SITUATION

The interseam distance between the seams 39 and 37 in the objective area is 20 to 25 m, while the interbed consists predominantly of fine-grained sandstone and rooted siltstone, thus medium-strength rocks.

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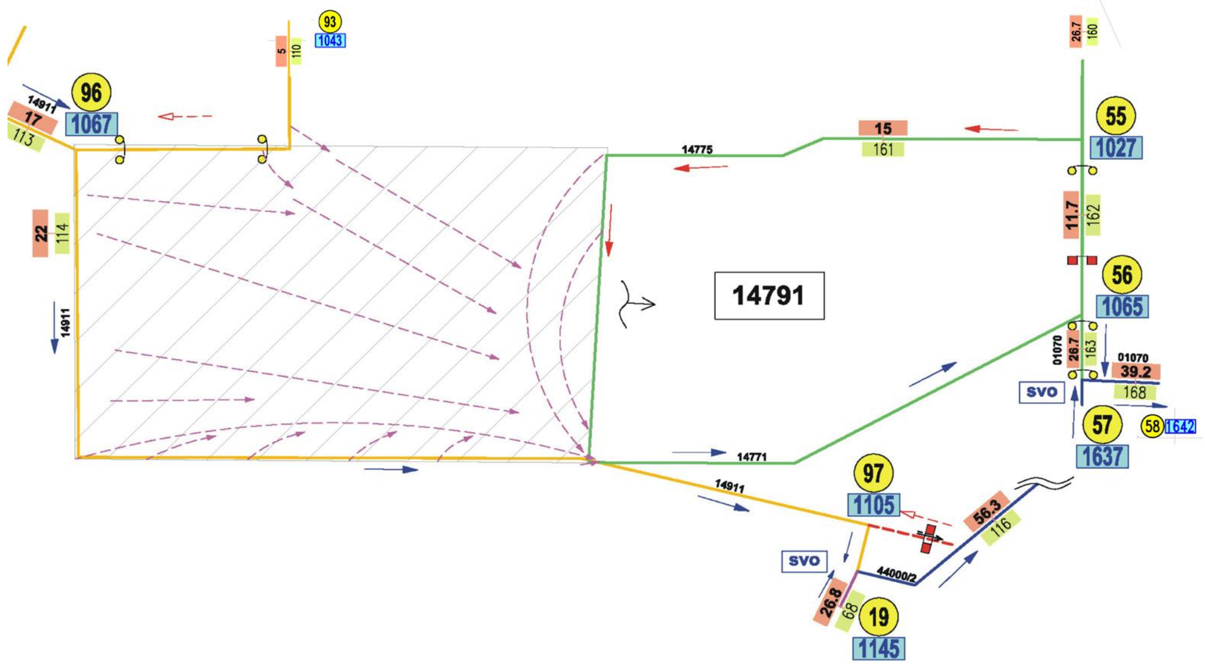
Failure of the intered of the seams 39 and 37 had occurred, when exploiting the face in the seam 37 and consequently the interbed was further affected, when driving roads in the seam 39.

The probability of drafts between mine workings in the seams 39 and 37 and next workings is still increased by driving the mine workings in the seam 39 in stope outlines of the seam 37 to protect the mine workings from the effects of bumps.

An important fact, increasing the risk of spontaneous combustion in this area is also mining the face in the seam 37 in floor coal, i.e. on the contact with the waste area of top coal, and a small coal seam between the seams 37 and 39, which is not developed in the entire area of the 4th block, but sporadically reaches a thickness of up to 1 m. The above situation demonstrates clearly the most likely airways for drafts - waste areas of the mined face in the seam 37.

After determining the potential airways it is necessary to proceed to a complex analysis of the depression image of this area.

WORKINGS IN SAC OF THE 39 SEAM	INITIAL AIR
WORKINGS IN SAC OF THE 37 SEAM	RETURN AIR
INITIAL WORKINGS	SHORT-CIRCUIT AIR
SHORT-CIRCUIT WORKINGS OUTSIDE SAC	BEGINNING OF SAC
WORKINGS OF OTHER SAC	END OF SAC
	NUMBER OF NODE POINT
AIR DOOR INSULATING WALLED	DEPRESSION IN NODE POINT (Pa)
AIR DOOR REGULATING WOODEN	VOLUME FLOW RATE OF AIR (m.s^{-1})
	BRANCH NUMBER



SVO=SAC (separate air compartment)

Fig. 1 Schema of the initial state of the seam 14791

In the modified model of the ventilation network (Fig. 2) the calculation using the SIT program was subsequently performed, of course for the entire mine network, and between the points 371 and 391 and between the points 393 and 372 the pressure gradients were evaluated. The pressure gradients between these points were determined as basic criteria of the risk of drafts between the levels of the 39th and 40th seams.

The calculation shows that the pressure gradient between the adjacent points 371 and 391 is only 5 Pa, which corresponds to the assumption from the ventilation network in the canonical schema of mine. However, between the points 393 and 372 the pressure difference is 40 Pa, namely towards the 39th seam (!), which indicates that the aerodynamic resistance of negative control at the end of SAC (separate air compartment) of the seam 37 is higher than needed and the control is "too close". However, 40 Pa is a value that could be considered for practice as a sufficiently small pressure difference, but with respect to the relative closeness of both points creates a potential risk of drafts through caved areas of the face No. 14791, namely towards the seam 39, which is in terms of the control of spontaneous combustion development an important finding, as its manifestations (increased CO concentrations) may be less evident in return air of the workplace itself and so the spontaneous combustion cannot be detected in time.

The draft will be affected by permeability of the environment between the seams 37 and 39. From the series of works dealing with this possibility the following findings according to [1 and 2] can be presented.

The danger velocity mine air circulation, which may contribute to the occurrence of spontaneous combustion is between (1.6 to 15) $\cdot 10^{-3}\ \ \mathrm{m \cdot s^{-1}}$.

For the reference case the value can be determined from the relation

$$v = \frac{dp \cdot k_1}{\eta \cdot l} \qquad [\mathrm{m.s^{-1}}] \qquad (1)$$

v filtration rate in rock environment [m.s^{-1}]

dp Pressure difference in tracked nodes [Pa]

k_1 permeability of rock environment [m^2]

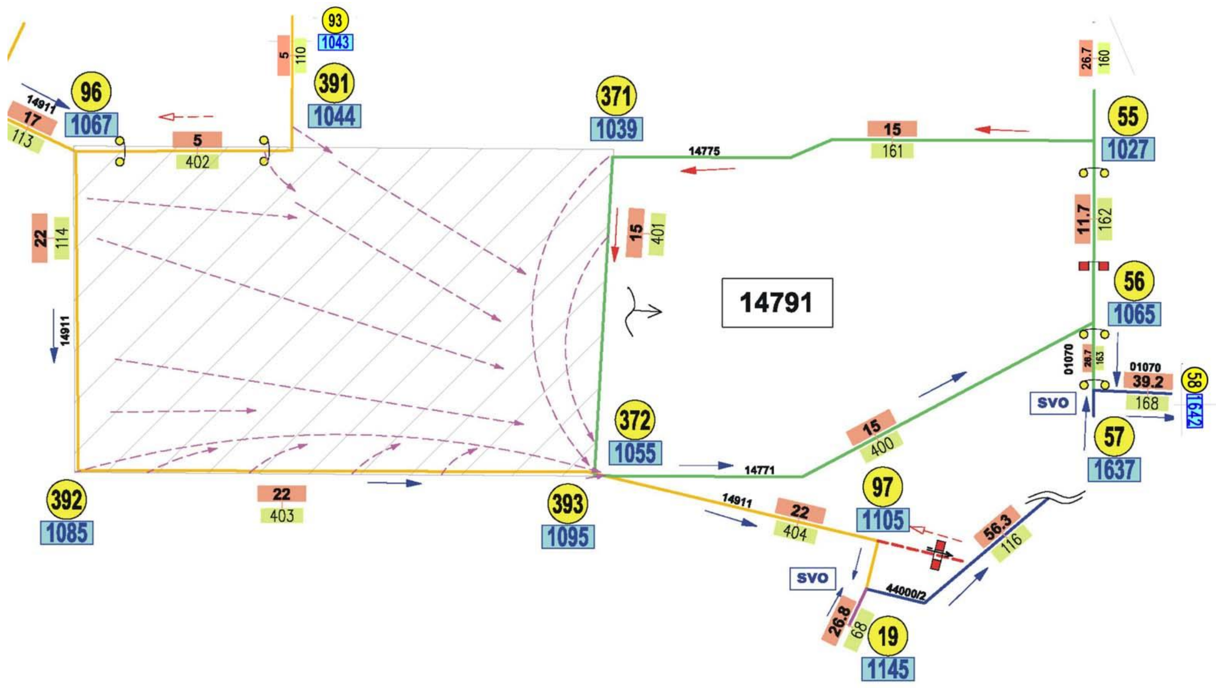
η dynamic viscosity (of air mass) [Pa.s]

l length of filtration flow (in our case, distance between seams) [m]

For a specific solution at $dp = 40\mathrm{Pa}$, $k_1 = 10^{-7}\mathrm{m}^2$, $\eta = 1{,}7 \cdot 10^{-5}\mathrm{Pa \cdot s}$, $l = 20\mathrm{m}$, it applies that

$v = 11{,}8 \cdot 10^{-3}\mathrm{m \cdot s^{-1}}$, which confirms the real risk of spontaneous combustion.

These results of investigating the permeability of rock mass especially of original rocks of extracted seams have an immense importance in future after the end of coal mining. Then the permeability becomes one of the decisive factors for realization of the risks associated with the output air of waste area from the closed and liquidated mine to the surface [3].



SVO=SAC (separate air compartment)

Fig. 2 Schema of the initial situation - in detail

Such analysis, for which also the SIT program, version 2.39, was used, results in two conclusions:

1. drafts through the caved area of the face No. 14791 can be expected from the workings in the seam 39 towards the face,
2. pressure gradient for these drafts is nearly eliminated by the negative control at the end of SAC of the seam 37 in the branch No. 163, aerodynamic resistance of this control is however too high.

It is now possible to determine another direction to provide measures reducing or eliminating the pressure gradient on the potential airway.

The first step is to determine, whether it is possible to achieve a further reduction of the pressure gradient by a change of the aerodynamic resistance of negative control in the branch No. 163.

3 PROPOSAL AND REALIZATION OF MEASURES

For this step the SIT program can be used so that the aerodynamic resistance of the branch No. 163 changed. After each change the mine ventilation network is recalculated and the verification is performed how the pressure gradient changes between the points, which we have previously identified as reference ones. After finding the aerodynamic resistance, which preferably eliminates the pressure gradient in the draft airway, the verification is performed, whether at this aerodynamic resistance the parameters required for ventilation at individual sites are observed, especially the volume air flow rate. Consequently the impact of the change of the aerodynamic resistance of the objective negative control on the stability of ventilation is evaluated, at least to the extent of SAC and further possible procedure is determined.

The presented procedure enabled by reducing the aerodynamic resistance of the branch No. 163 from the value of 0.80237 $\mathrm{kg \cdot m^{-7}}$ to 0.62237 $\mathrm{kg \cdot m^{-7}}$ to achieve nearly a complete elimination of the pressure gradient between the points 393 and 372, which is 1 Pa, which is a negligible value. (Fig. 3). Also the effect on the volume air flow rate led through both SACs is not significant and so the ventilation could be considered sufficient.

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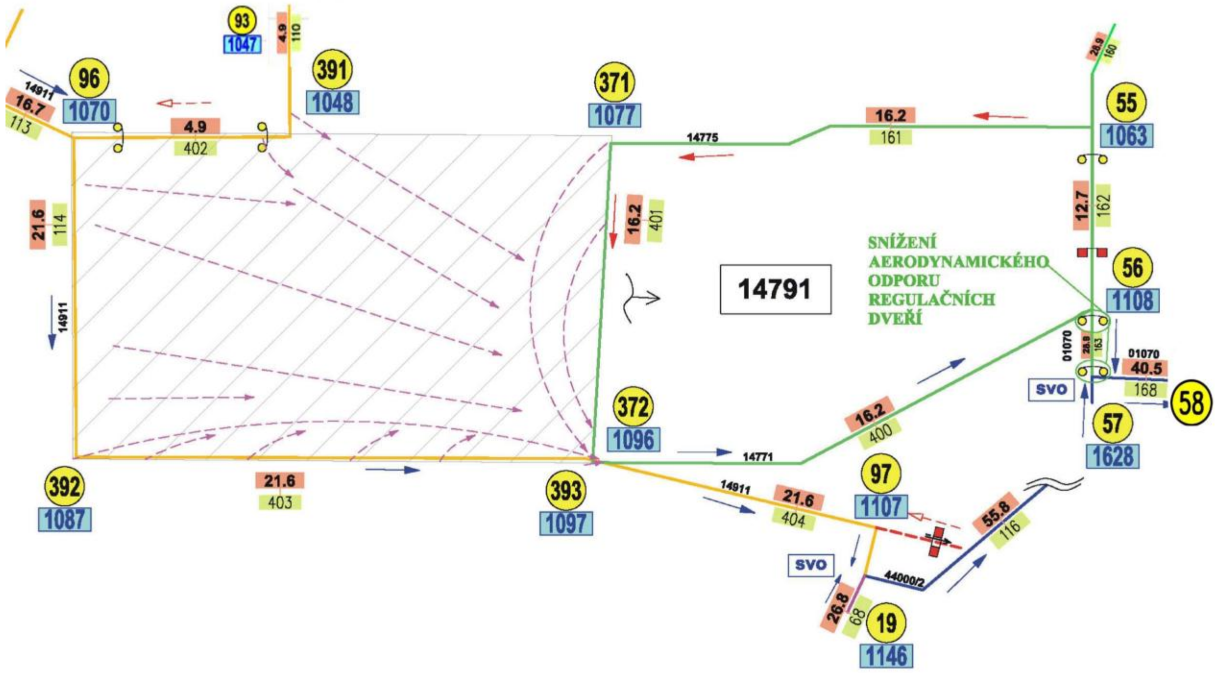


DECREASE OF AERODYNAMIC RESISTANCE OF DOOR REGULATORS
SVO=SAC (separate air compartment)

Fig. 3 Decrease of the aerodynamic resistance of the door regulators

A more detailed analysis of the situation shows that the change of the aerodynamic resistance revealed itself in increase of the pressure difference between the points No. 391 and No. 371 from 5 to nearly 30 Pa.

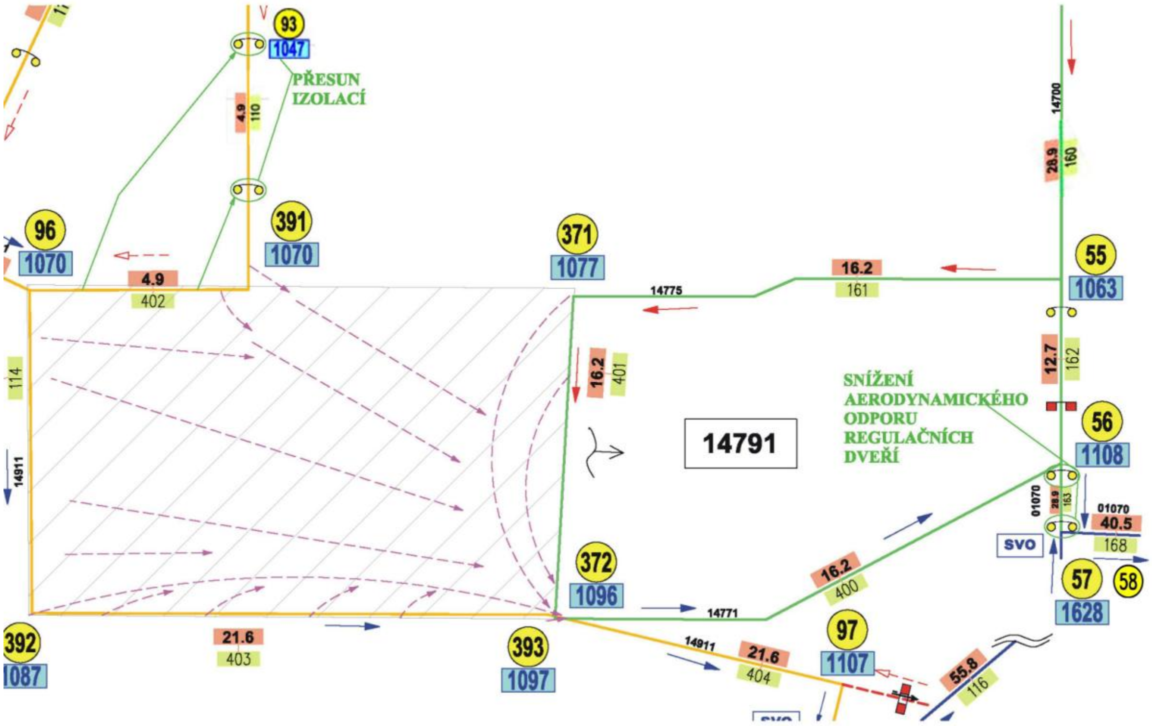
Note that the pressure difference between the points No. 371 and No. 372 increased, thus the face pressure difference, from 16 to 19 Pa. The pressure gradient through the face is also one of the criteria that must be tracked, considering the fact that the increase in the pressure gradient between the initial and return sides of the face has a negative impact on drafts through the caved area, which are the greater, the greater is this pressure gradient at maintaining the aerodynamic resistances of the face and the caved area. However, the increase of the pressure difference by 3 Pa is not significant and can be evaluated as a steady state.

The analysis of the 1st step results in a definite conclusion that we have managed to reduce significantly the pressure gradient in the assumed airways. The question is, whether it is possible to reduce further the pressure gradient.

To answer the question, it is necessary to return to the schema of the situation and note the location of isolations in both SACs.

We focus directly on the short-circuit connections within the SAC of the 4th block of the 39th seam between the points No. 93 and 96 (and between the previously entered point No. 391). The total pressure difference between the points 93 -96 is 23 Pa. However, as much as 22 Pa of the pressure difference reveals itself between the points 391 and 96. The reason is that the isolations of the branches 93 -391 -96 is carried out through the objects built between the points 391 and 96, which comprise the best part of the aerodynamic resistance of the branches 93 -391 -96.

How can this information be used to reduce the pressure gradient through the draft airways? To eliminate the pressure difference between the points No. 391 and 371, it is necessary to increase the depression induced by the main fan in the point 391 by the value of 29 Pa, the pressure difference to be equal to 0.



DISPLACEMENT OF ISOLATIONS
DECREASE OF AERODYNAMIC RESISTANCE OF DOOR REGULATORS
SVO=SAC (separate air compartment)

Fig. 4 Transfer of the isolations from the branch between the points 96 and 391 to the branch between the points 391 and 93.

We offer a solution: If we place between the points 93 and 391 the aerodynamic resistance of the isolation between the points 391 and 96, while maintaining the volume air flow rate through the short-circuit connections of 93 -391 -96, the increase of depression should occur induced by the main fan (hereinafter referred to as MF) in the point 391 by the value of about 22 Pa.

This solution can be verified using the SIT program so that the aerodynamic resistance of the branch No. 402 (between the points No. 391 and 96) will be given by the aerodynamic resistance corresponding to the mine working without isolation objects and in the branch No. 110 (between the points No. 93 and 391) the aerodynamic resistance of isolation is added to the aerodynamic resistance of the working. Consequently the calculation of the ventilation network will be performed and the impact of the simulated changes on the network will be evaluated. The calculation is illustrated in Fig. 4.

Based on a mere comparison of Fig. 3 and Fig. 4 one can say that the assumption was confirmed and that the location of the isolation between the points 391 and 96 was from the perspective of avoiding drafts between the mine workings in the seams 39 and 37 was chosen improperly.

The measures set by the SIT program to reduce the probability of drafts between the workings in the seams 39 and 37 are therefore as follows:

1. to reduce the aerodynamic resistance of negative control at the end of SAC of the seam 37 in the branch No. 163 (at mine e.g. by direct measurements of pressure gradient on the control when being released up to the achievement of the required pressure gradient),
2. to displace the isolations from the branch No. 402 to the branch No. 110,
3. to verify the taken measures by measurements of the pressure image of this area.

4 POSSIBLE EMERGENCY CONDITIONS

Just before the implementation of these measures it is suitable, using the calculation of the ventilation network, to verify again the impact of the conditions, which deviate from a normal operation, on the specific part of the ventilation network. The following cases could occur:

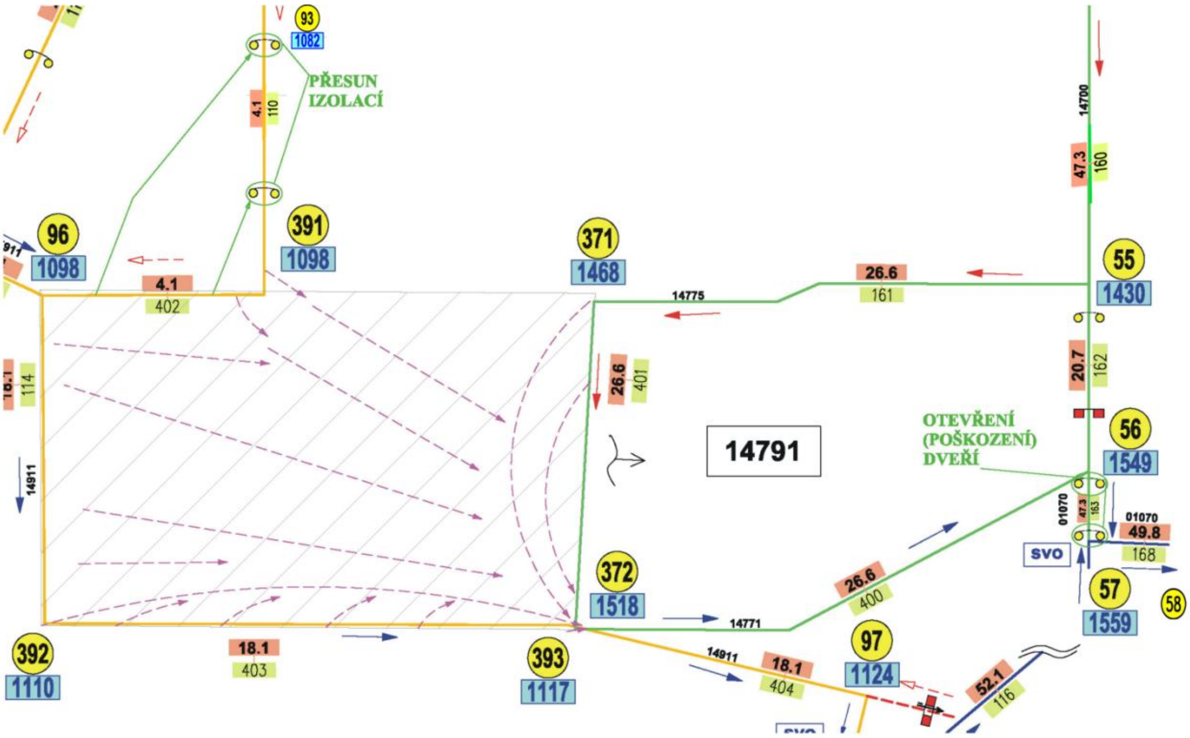
1. opening the DOOR REGULATORS in the branch No. 163
2. increase of the depression induced by the main fan
3. decrease of the depression induced by the main fan

4.1 Decrease of the aerodynamic resistance of the negative control in the branch No. 163

The negative control in the branch No. 163 between the points No. 56 and No. 57 is, as previously shown, crucial for maintaining a minimum pressure gradient between the seams 37 and 39.

What happens in case of e.g. a damage to the door or a lack of technological discipline during transport, when both air doors remain open?

The answer can be found through the verification by the calculation of the ventilation network using the SIT program. We will enter to the branch No. 163 a aerodynamic resistance corresponding to the mine working without a negative control (which is in terms of a damage or opening the doors the worst case), then start the calculation and evaluate the results.



DISPLACEMENT OF ISOLATIONS
OPENING (DAMAGING) THE DOOR
SVO=SAC (separate air compartment)

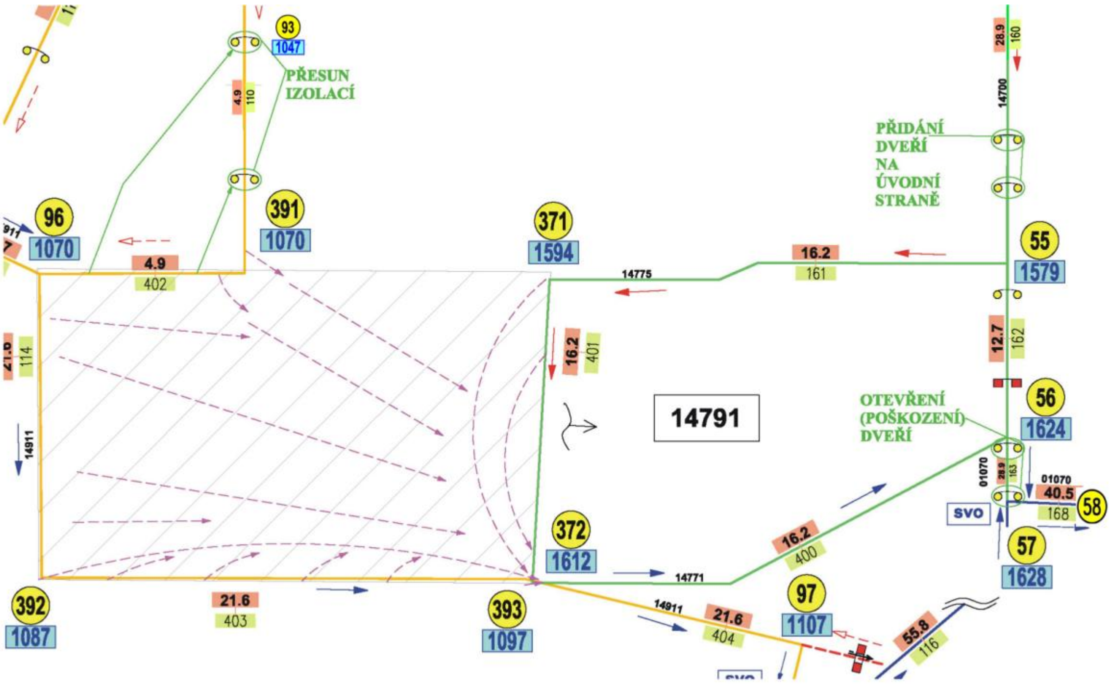
Fig. 5 Opening (damaging) the doors in the branch 163

The calculation is plotted in Fig. 5.

It is obvious that damaging or opening the pair of doors have a quite decisive effect on the pressure gradients between the tracked points . The pressure gradients through the caved area (between the nodes 372 and 393) increase up to values about 400 Pa. These are the values that affect drafts also while opening a pair of doors and can act as a "blower" that by pulses drives the fresh air to the caved areas.

Let us verify the impact of such “opening the doors” by a mathematical simulation of the aerodynamic resistance of the door regulators which ensure the same volume air flow rate through SAC, but will be placed in the branch 160, thus in the initial part of SAC. The assumption is that after releasing the doors in the branch 163, which we will simulate in the way mentioned above, any increase of the volume flow rate will not occur, because this will be controlled by the air doors in the branch No. 160. The calculation is plotted in Fig. 6.

The results show that the volume air flow rate was maintained, but the pressure gradient between the tracked points 372 and 393 still increased. Mathematical modelling demonstrates, how it is possible by an improperly located air control to affect significantly in a negative way the depression conditions in the ventilation network, thereby creating favourable conditions for drafts through waste areas.



DISPLACEMENT OF ISOLATIONS
ADDING THE DOORS AT THE INITIAL SIDE
OPENING (DAMAGING) THE DOOR
SVO=SAC (separate air compartment)

Fig. 6 Adding the doors at the initial side

So it is necessary to take further measures. The best is to install on the pair of the doors sensors detecting closing the door wings, or better yet, sensors continuously measuring the pressure gradients between the points before and behind the pair of doors, which show us the immediate condition of the controlling air objects.

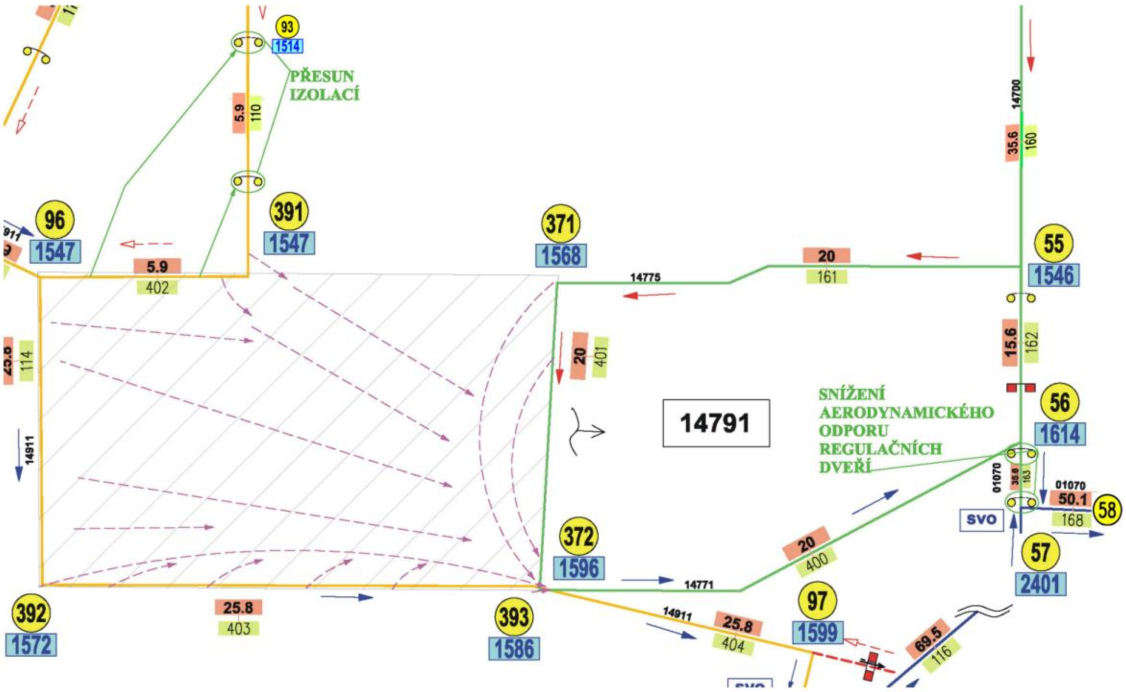
4.2 Increase and decrease of MF depression

The effects of the increase of MF depression in the ventilation network can be also tracked by means of the SIT program, changing the mathematical entry of the feature in the branch No. 181 (MF – exhaust shaft No. 2). For the demonstration purposes the initial value of the fan depression was changed from 2350 to 3500 Pa.

The list of the calculation carried out is plotted in Fig. 7.

The figure shows that the pressure difference between the points 393 and 372 increased compared to the state proposed from 1 to 10 Pa and between the points 391 and 371 from 7 to 21 Pa.

Despite the fact these are values in any way significant, it is necessary to deal with them, because we can certainly imagine situations different from the example proposed, where the increase of pressure differences in the assumed airways are more important.



DISPLACEMENT OF ISOLATIONS
DECREASE OF AERODYNAMIC RESISTANCE OF DOOR REGULATORS
SVO=SAC (separate air compartment)

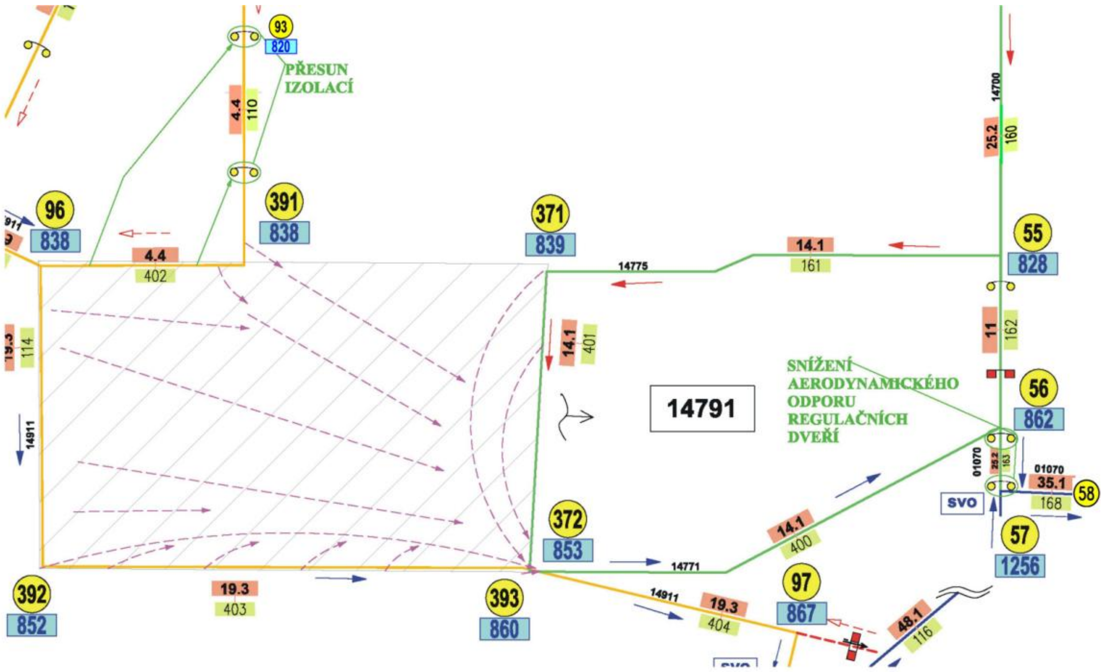
Fig. 7 Increase of the MF depression to 3500 Pa

Like the MF-induced increase of depression also its drop can be simulated.

In the branch No. 181 (exhaust shaft No. 2) representing MF this time the pressure of 1800 Pa was entered and calculation carried out as in Fig. 8.

The calculation shows still less important effect than in case of the MF depression increase, which is also due to the smaller pressure difference from the initial MF depression.

Even here, however, it is necessary to deal with the change of MF function mode in cases, where decisions are made on the ventilation optimization in spontaneous combustion hazard-prone areas.



DISPLACEMENT OF ISOLATIONS
DECREASE OF AERODYNAMIC RESISTANCE OF DOOR REGULATORS
SVO=SAC (separate air compartment)

Fig. 8 Decrease of MF depression to 1800 Pa

5 CONCLUSION

In this paper we demonstrated, how the SIT program version 2.39 could be utilized to solve the optimization of ventilation in spontaneous combustion hazard-prone areas.

The procedure of reduction of unfavourable influences of drafts on the process of spontaneous combustion of coal, or its recovery, will be then the same and it can be preliminary formulated as follows:

1. Measure the depression image of the affected area (preferably the entire mine) before making the seat of fire accessible.
2. Analyze the state of rock mass, distribution of pressure gradients of the assessed area and identify possible airways.
3. Propose measures to reduce dangerous drafts of mine air to the phases before, during and after the disclosure of the seat of fire.
4. Verify using the mathematical model the correctness of specified measures.
5. Implement measures at the mine.
6. Verify the correctness of implemented measures by measurements at the mine.

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RESUMÉ

Jako ukázka optimalizace pomocí regulace ve větrní síti v tomto článku sloužila situace ze 4. dobývací kry Lokality Jan-Karel Dolu ČSA v Karviné z roku 2004. V roce 2004 byla v této dobývací kře současně provozována hornická činnost ve 37. sloji spočívající v dobývání porubu č. 14791 a ve 39. sloji spočívající v ražbě přípravných děl pro porub č. 14936.

Z provedené analýzy a podrobného rozboru předmětné oblasti lze usuzovat, že bude docházet k průtahům větrů závalovým prostorem porubu 14791 od děl děl ve 39 sloji směrem k porubu. Dále z rozboru plyne, že tlakový spád pro tyto p průtahy je téměř eliminován negativní regulací na konci SVO 37. sloje ve větvi č. 163, aerodynamický odpor této regulace je však příliš velký.

Možná opatření ke snížení pravděpodobnosti průtahů mezi díly ve 39. a 37. sloji jsou tedy taková, že by se měl snížit aerodynamický odpor negativní regulace na konci SVO 37. sloje ve větvi č. 163 (v dole např. přímým měřením tlakového spádu na regulaci při jejím roztěsňování až do dosažení požadovaného tlakového spádu), dále přemístit izolace z větve č. 402 do větve č. 110 a na závěr ověřit provedená opatření proměřením tlakového snímku oblasti.