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NUMERICAL MODELING OF HEAT AND MASS TRANSFER DURING HOT AND COOL AIR MIXING IN AIR SUPPLY SHAFT IN UNDERGROUND MINE

The article deals with the suction method of ventilation of the mine. Fresh air in the mine is supplied by air supply shaft (or shafts), and part of the air in the cold season, warm air heating installation in and through the hot-air channel flows into the shaft. The results of the process of mixing hot and cold air streams in the air-supply shaft, as well as air traffic on the trunks, taking into account the temperature and velocity, which are made on the mathematical model developed in the software package Solidworks flow simulation.

The temperature in the hot-air heating air channel must be adjusted depending on the outdoor temperature. In the article the option of air heating installation of air heating, in which the air temperature in the air heater is channel 9 °C at ambient temperature of –20 °C. Considered air mixing process and the depth of the barrel depending on the reinforcement (channel width is less than the barrel diameter). It is also considered an option at the hot-air channel width equal to the diameter of the barrel, which characterizes the process airflow temperature changes in the depth of the trunk. The third option of using air heating installation, discussed in the article suggests the location of air heating installation in walls pithead. It is shown that heating of the air passing through heat exchangers installed on the perimeter of a building , provides necessary temperature of the air in the shaft.

Key words: *downcast shaft, main fan, air, mixing, warm, cold.*
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Introduction

Underground mine ventilation may use either suction or blowing. Which method to choose depends on ground conditions, gas content of mine air and natural draft [2, 4, 6, 12].

With suction ventilation, fresh air is fed to a mine via one or more air supply shafts. Return air is removed from the mine along a ventilation shaft (shafts).

Air is pushed in a mine by a mine main fan (MMF) and, if required, subsidiary draft sources (fans or fan installations) arranged within the mine ventilation network in accordance with the design [8]. In a mine ventilation network, the main resistance falls at shafts. The structure of a shaft furniture is conditioned by the functional purpose of the shaft [7], and the shaft furniture structure has influence on miscibility of cool and hot air flows when air across the shaft section reaches a required temperature [9, 10] (the air to feed underground openings should have temperature not less than +2 °C).

Body of the paper

Air heater channels in potash mines provide, as a rule, one-way air feed in a shaft, which complicates mixing of hot and cool air inflowing through the shaft head in winter [2, 3]. A feature of air entering air supply shafts in cold season is uneven temperature across and along the shafts (as per measurements taken in operating mines). This results in damage of tubing seal assemblies and, thus, in growth of ice bodies; for this reason, to keep temperature above zero in a shaft, the hot air temperature is increased, which elevates expenditures connected with the mine ventilation [4].

This paper considered air flow in an air supply shaft in case of the suction ventilation mode and gives modeling data of Solidworks flow simulation on mixing of hot and cool air flows in the air supply shaft of a potassium mine.

Air fed in an air heater channel had temperatures differing by a degree only, i.e. +7°C, +8°C and +9°C (at the same temperature of air inflowing through installations above ground); this allowed detecting considerable differences in the temperature measured section-wise in an air supply shaft (air supply shaft no. 2, Berezniki Mine-2, Uralkali). It is worth saying that in the area of the Upper Kama Potash–Magnesium Salt Deposit, the outer air temperature may go as low as –36 °C; in autumn and spring, and partly in winter, when the outer air temperature is much higher than –36 °C, with a view to saving energy sources for heat generation, air heater efficiency should be reduced so that air temperature in the shaft is close to +2 °C or a little bit higher, but not +15...+20 °C [2, 4–5, 12].

Fig. 1 illustrates hot and cool air mixing length-wise an air supply shaft. Air fed through air heater channel has volume of 147.27 m^3/s and temperature of +9 °C; air entrained via installations above ground has volume of 20.71 m^3/s and temperature of –20 °C.

Fig. 1a shows how hot and cool air flows mix along the air supply shaft and the air temperature varies; Figure 1b depicts distribution of air velocity epures length-wise the shaft versus the shaft furniture. The air flow velocities have essential influence on the process of mixing of hot and cool air [11].

It is seen in **Fig. 1** that hot and cool air flows mix gradually length-wise the shaft, and the required heating conditions in the air supply shaft are never reached even at the level of –50 m. An important factor for air flow mixing is also the air heater channel and shaft juncture. It is seen in Fig. 1a that subzero air temperature is generated immediately beneath the air heater channel, and is governed by the width and shape of the channel (channel width is 5.2 m; shaft diameter is 7.0 m).

Mixing of air flows depends also on the shaft furniture and takes places in shafts 50–70 m deep, sometimes deeper.

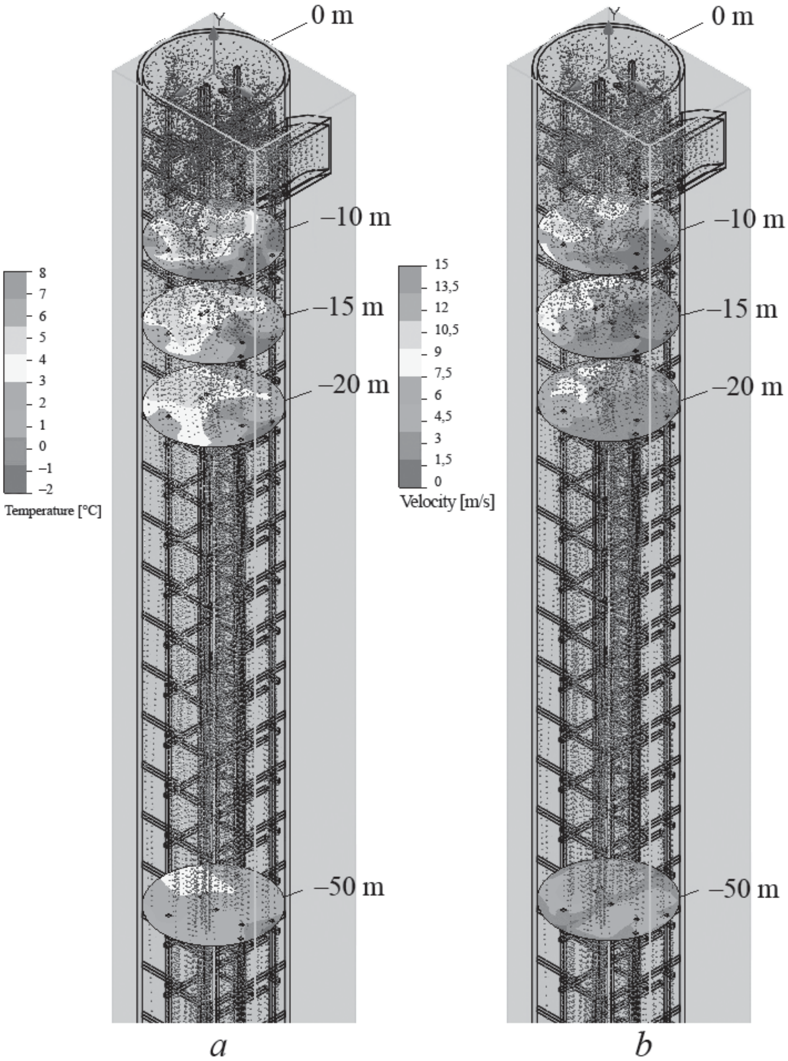

Fig. 1. Modeling of (a) mixing of hot and cool air flows and (b) air flow velocities in an air supply shaft

Fig. 2 shows modeling data on hot and cool air mixing in an air supply shaft when the width of an air heater channel equals the diameter of the shaft (**Fig. 2a**) and when the air heater is installed in the walls of the shaft head [1] with air heater channel shut (**Fig. 2b**). It is seen in the figure that when the air heater channel width is equal to the shaft diameter, no complete mixing of hot and cool air does happen down to 35 m.

Furthermore, modeling yields that air mixing is non-uniform across the shaft.

When the air heater is arranged in the walls of the shaft head, the shaft temperature is positive as early as level ±0 [1].

Conclusions

Based on the analysis of modeling data on mixing of hot and cool air flows in an air supply shaft, the following conclusions can be drawn:

- the uniform mixing of hot and cool air flows at the mouth of the air supply shaft in cold seasons will permit uniform positive temperature across and along the shaft, which will enable cost saving of the shaft operation;
- to ensure uniform mixing of air flows at minimized costs in case of one-sided juncture of air heater channel and the shaft, it is required to:

— adjust air feed in the air heater channel with respect to the outer air temperature;

— control air heating temperature in the air heater channel;

— check air temperature across and lengthwise the shaft;

- the issue of mixing of hot and cool air flows in air supply shafts is to be analyzed at a mine design stage with regard to all probable factors;
- it is advisable and expedient to heat air using air heaters installed in walls along the perimeter of a shaft head.

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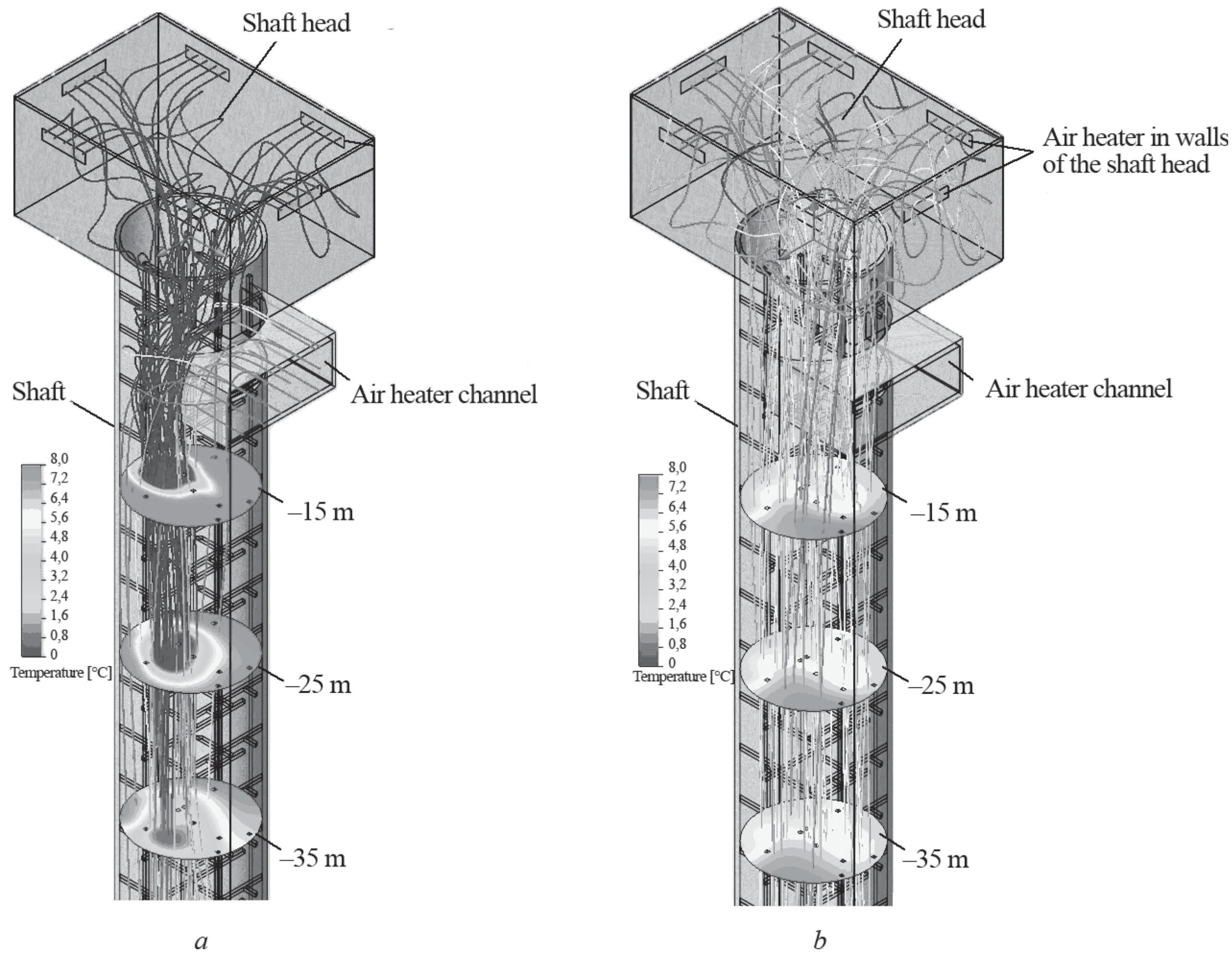

Fig. 2. Modeling of mixing of hot and cool air flows in air supply shaft (a) when the width of the air heater channel is equal to the shaft diameter and (b) when the air heater is installed in walls of the shaft head

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