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MINIMISATION OF ATMOSPHERE POLLUTING BY MEANS OF MINE GEOTHERMAL POWER INSTALLATIONS

A. Minaev, V. Kostenko, M. Shaforostova

Donetsk National Technical University

Abstract

The paper considers the problem of using geothermal energy of mines. Existing installations have a number of drawbacks which are mentioned in the paper. We have studied the use of similar geothermal energy installations and suggested new engineering solutions. They are aimed at reducing harmful emissions into atmosphere and increasing the economic efficiency. We have studied the functioning of these installations and described their basic parameters. It is shown that the given facilities can work not only at operating mines, but also at the mines that have been liquidated.

Keywords: geothermal energy, mining excavations, emission, environment

In Lissabon's declaration it is mentioned that in the nearest future it is necessary to create and use power generating installations with zero emission of pollution into natural environment. One of the ways of obtaining non-polluting energy is the use of geothermal resources.

In mining industry the method of obtaining geothermal energy from subsoil areas can be used to provide mines and surface objects with thermal energy. This technique can be used both at operating and dormant mines.

Nowadays the way of obtaining geothermal energy developed by Baumgertner S., Gerar A., Barma R., Vi P. is well known. This method presupposes the fact that in order to obtain geothermal energy vertical or inclined excavations are made from the surface up to the depth where the temperature of rocks exceeds the temperature of boiling water. Between the adjacent excavations it is necessary to create an area of permeable fissured rock mass, which is called underground geothermal heat exchanger. A heat carrier (a liquid or a gas) is let into one of the excavations, then it goes through the heat exchanger where it is heated and the heated water comes to the surface. Then the heat carrier is let out from the other excavation and the accumulated energy is utilized.

However, the technical result is not obtained due to the following facts:

- efficiency of this method is insufficient as the amount of water supply to the heat exchanger is limited because of the so called "thermal gap" when cool water comes to the excavation;
- high cost price of the obtained energy because of high cost of designing, preparations, making mining excavations and nature protection measures;
- this method has low reliability as the spaces in the underground heat exchanger can be filled with rock particles or crystals of salts formed in water.

The closest analogue is the way of obtaining geothermal energy, which is taken out from a mine by a stream of mined out air. This method is offered by Sulkovsky I., Drenda J., Rozansky Z. (Technical University of Ostrava, Czechia).

This method presupposes the following:

- air is supplied from the surface through the shafts in mining excavations;
- air runs through a network of operating mining excavations with permissible speed due to the pressure of fans and heating from rocks up to the temperature about 25^0C;
- air is supplied to the surface through a ventilating shaft and accumulated geothermal energy is utilized for the needs of consumers using, in particular, a «the thermal pump».

The range of maximum and minimum permissible air speeds for different types of mining excavations is determined by the requirements of «Safety Rules in Mines». The same document limits air heating up to the temperature no more than 25^0C because this value is critical for workplaces in underground conditions from the point of view of thermal influences on a human body.

Peculiarities of this method are the following:

- the heat carrier is supplied from the surface into underground excavations and runs through the network of mine excavations;
- geothermal energy saved by the heat-carrier is utilized by consumers.

In this case the effective technical result is not achieved because:

- the efficiency of the method is affected by the limitation of the heat-carrier expenses in a network of mining excavations under the factor of speed;
- the rate of energy supply from the bowels is low because the heat is given only by a part of the rock mass located near the contour of operating mining excavations during a rather short period of their existence. In Donbass the time of existence of one kilometer of local preparatory excavations is 1,5 - 2,5 years (in the countries of Europe this time is shorter), for stope excavations the time of existence within an invariable rock contour is only about several hours, and this period is not enough for cooling considerable volumes of rock mass;
- mine ventilation is too expensive and has a negative influence on the natural environment because ventilation facilities use the power obtained from fossil fuels, which belong to exhaustible sources of energy.
- the field of this method application is restricted as it can be implemented effectively in the conditions of excavation networks ventilation in operating mines. After a mine has been closed the use of the method is unreasonable due to the high costs and low efficiency.

The specialists of Donetsk National Technical University suggest using the heat from the rock mass areas left after minerals extraction. This approach is based on the problem of improving the method of obtaining geothermal energy from a heat carrier, which is supplied from mine excavations. This method has the following advantages:

- increase of efficiency;
- the field of its application includes liquidated mines;
- it is possible to obtain more geothermal energy from the rock mass;
- decrease of costs and negative influence on the environment due to reducing the expenditure of electric power obtained from exhaustible sources of energy.

The given problem can be solved in the following way. The known method of obtaining geothermal energy presupposes heat carrier supply from the surface to underground mine excavations, its movement through a mine excavations network and utilization by consumers of geothermal energy accumulated in the air. In this case the heat carrier supplied from the excavations is directed into a channel made in the mined-out space. Thus the time of finding the heat-carrier in the channel is defined by the formula:

$$\tau = \frac{0{,}1 \times \rho \times c \times F^2}{\lambda \times \Pi^2} \times \ln(T_m - T_b), \tag{1}$$

where: ρ - heat-carrier density, kg*m^{-3};

c - heat-carrier thermal capacity, J*kg^{-1}*K^{-1};

λ - factor of heat conductivity of the heat-carrier, W*kg^{-1}*K^{-1};

F - the area of cross-section of the channel, m^2;

Π - channel perimeter, m;

T_m - temperature of a rock mass, K;

T_b - air temperature at the channel input, K.

The cause-effect relation of the characteristics which make up the essence of the method is explained by the following. The channels created in the mined-out space allow collecting thermal energy by the heat-carrier from the surface of the bare rocks. In the process of extracting energy it is renewed by means of heat transfer from the bowels. The research has shown that if the length of the heat-carrier path in underground excavations reaches 500 m and more, it leads to the dynamic balance in the heat transfer process, which remains stable for dozens of years. In this case the amount of the obtained thermal energy is proportional to the area of channels surface and the difference between the temperatures of excavations walls and the heat-carrier. Thus, the creation of artificial channels gives the possibility of improving the method by means of increasing the amount of geothermal energy obtained from the rock mass. The use of permanent excavations of existing mines gives the possibility of reducing essentially the expenses for this method implementation.

The field of applying this method can also include liquidated mines. The obtained ecologically pure geothermal energy reduces the negative influence of mines on the environment. It is provided by decreasing the expenditure of the electric power which is spent on heat-carrier movement through the excavations and the heat exchanger.

The essence of the method is shown by a particular example of obtaining geothermal energy. Figure 1 provides the scheme of this method implementation.

The way of obtaining geothermal energy is realized as follows. Air is used as the heat-carrier. It is supplied from the surface through vertical shaft *1* to mining excavations through which the air is supplied *2*. From these excavations air comes to stope excavation *3*, and then to the mined-out space. Regulation of air streams directions and air expenses is carried out by means of portable ventilating crosspieces with regulators *4*. In the mined-out space formed after coal extraction channels *6* are made parallel to stope excavation with the interval 40 - 70 m. These channel represent a square excavation with dimensions 2 x 2 m. Channels *6* are connected with the excavations supplying air *2* and taking away air *5* where we made ventilating crosspieces *7* between the pairs of channels in order to provide the opposite direction of air movement in the adjacent channels. Thus, excavations *2* and *5,* channels *6* and crosspieces *7* taken together form a labyrinth heat exchanger, in which the air, moving along a serpentine path, washes the whole area of the mined-out space, heats up to the temperature of the surrounding rock mass and collects geothermal energy.

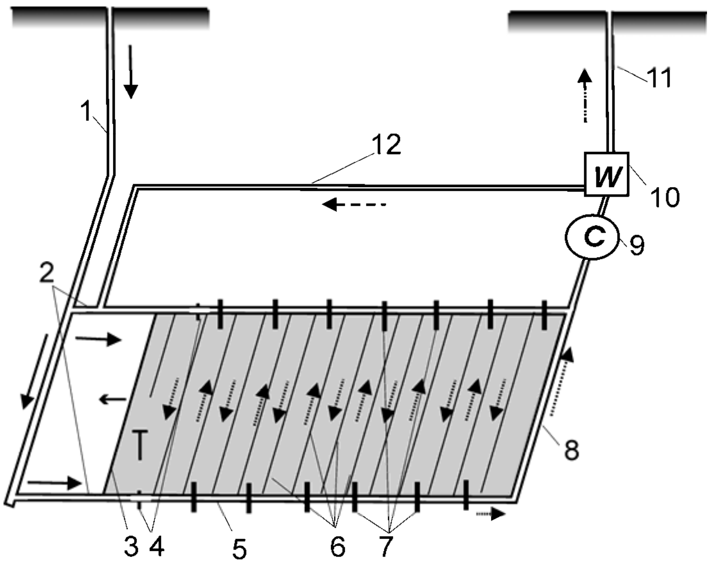

Figure 1 – Technologies of savings resources using geothermal energy
1 – vertical mine shaft through which air is supplied; 2 – excavation supplying air;
3 – stope excavation; 4 – ventilating crosspiece with a regulator;
5 – excavation that lets out air; 6 – channels in the mined-out space;
7 – ventilating crosspiece; 8 – excavation that lets out air; 9 – compressor;
10 – vortical pipe; 11 – ventilating mine shaft; 12 – excavation that lets out cold air

The period of the heat-carrier staying in the channels is defined by formula (1) where:

ρ - heat-carrier density = 1,29 kg*m^{-3};

c - heat-carrier thermal capacity = 1000 J*kg^{-1}*K^{-1};

λ - factor of heat conductivity of the heat-carrier = 0,024 W*kg^{-1}*K^{-1};

F - the area of cross-section of the channel = 4 m^2;

Π - channel perimeter = 8 m;

T_m - the temperature of rock mass = 293 K;

T_b - air temperature at the channel input = 313 K.

Thus, the minimum period of air staying in the geoheat exchanger makes up:

$$\tau = \frac{0{,}1 \times 1{,}29 \times 1000 \times 16}{0{,}024 \times 64} \times 3 = 456s$$

This requirement can be achieved under the following conditions. The length of air serpentine path in the channel is about 450 m (it consists of two pieces 200 m long (equal to the length of the stope face), the distance between them is 50 m) and the speed of air is about 1 m*s^{-1}. Air temperature at the channel output is equal to 40^{0}C. The energy received by the heat-carrier in the heat exchanger while it passes from the input to the output is equal E=50∗10^{-6} J.

When mining works are advanced and the channel becomes longer the heat carrier speed can grow considerably. The results of the researches are provided in table 1.

Table 1 – The influence of geoheat exchangers parameters on collecting geothermal energy

Length of the channel, L, m	500	1000	1500	2000
Speed of air, V, m/s	1	2	3	3
Energy of the heat-carrier, Q∗10^{-9}, J	0,0516	0,1032	0,4644	0,6192

Heat resources, which come from bowels, are sufficient for the heat exchanger operation during several centuries. From the geoheat exchanger warm air goes to excavation *8*, and then compressor *9*. Compressor 9 activates air motion by a network of operating mining excavations. From the compressor warm air comes to vortical pipe *10* where it is divided into two streams – hot and cold. The hot stream containing the heat accumulated in the geoheat exchanger goes to the surface through ventilating shaft *11* and comes to consumers. The cold air stream comes through excavation *12* and recirculates in mining excavations *2* which supply air.

The offered way of obtaining geothermal energy consists in the use of rock mass heat. From the geoheat exchanger geothermal energy comes to a heat processing device. In this particular case it is a vortical pipe where the stream of air molecules which have the greatest energy is separated and supplied to consumers.

This method employs an additional geoheat exchanger where geothermal energy is obtained from the mined-out area of a deposit. It allows increasing the amount of energy obtained from the bowels and improving the process of obtaining energy in comparison with known engineering solutions.

The geoheat exchanger can function practically constantly. The time of its operation is conditioned by mining excavations stability and equipment deterioration. Considerable area of artificial channels in the mined-out space and the access to them with the purpose of repair works give the possibility of increasing the reliability of the equipment for obtaining geothermal energy. Taking into account the configuration and the great length of the geoheat exchanger channels we consider impossible "breakdowns" of the cold heat-carrier from mining excavations.

The use of geothermal energy for air heating essentially reduces the expenditure of exhaustible power sources (natural gas or coal), so this method has positive ecological effect. As the fuel expenditures are lower in this case, the cost price of mining production (including geothermal energy) is reduced considerably.

We suggest the introduction of such facilities at operating mines, so the costs of their installation will not be great as there is no need of exploration works and the cost of designing works is insignificant.

As for the current expenses they will tend to reduction due to the difference in the cost price of the energy obtained using geothermal power facilities and the energy obtained on the basis of traditional approaches. Besides, the obtained energy can be used for obligatory ventilation of mine space in order to reduce the expenses for mining works safety. Moreover, the obligatory tax payments for the pollution of environment will be lower.

Thus, the decrease of current and capital expenses leads us to the conclusion about the economic efficiency of introducing mine geothermal power facilities.

It is a well-known fact that after exhaustion of mineral resources the proprietor has considerable expenses for maintaining the industrial area in safety. To avoid these expenses and to receive additional benefits it is possible to use the mine as a generator of geothermal energy for many years.

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