The Construction Based on Leidenfrost’s Effect in Mining

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Abstract. In the context of growing demand for mineral resources extracted by the closed method, the mining industry is being improved, methods of increasing the efficiency of underground mining, their safety are being developed. Safety is being improved by improving existing safety tools, such as mountain supports. One of these improvements to the existing mountain support can be called the design described in this article. «Construction on the basis of the Leidenfrost’s» effect is an improved type of reinforced concrete mountain support having its own unique features described in this article. By passing the design in this article will be considered and analyzed the effect of Leydenfrost’s, the causes of its occurrence and the possibility of using its causes of its occurrence in the mining industry, namely in the improved rock support, which will contribute to a more efficient production of useful resources. On past this will be a comparative analysis with the identification of shortages of the old version of the mountain support and their removal in the new version of the mountain support. And the use of mining support by-products of production in order to reduce the energy consumption in the production in General.

1. Introduction

In the modern world, the demand for resources produced by the mining industry is increasing. This is directly related to the need for these resources as components for the creation of modern goods. With the growing demand for resources, the scientific base of the mining industry is also growing, namely, improving the methods of mining, improving the technical means of extraction and improving the security of excavation.

The traditional methods of extraction of minerals include: open, closed combined. For a more modern include borehole, and dredging methods. To maintain safety in the workings, developed by closed, combined methods, mountain supports are used. Mountain supports come in the following forms of cross sections: round, rectangular, trapezoidal and rectangular vaulted. The following types of materials are used to create mine workings: wood, concrete, metal, concrete and anchors. [1-6] The type of materials and the shape of the cross sections of the mountain supports affect the duration of use of the mountain, so the wooden supports of any form is referred to as temporary, as the life of the wooden support is very limited, which cannot be said about the concrete or anchorages, which are referred to as permanent mountain mounts.

Thus it is possible from all types of mountain struts can be identified the most effective in all senses of the support: concrete trapezoidal mountain support. But this support has several significant disadvantages: water flooding of the base of the mine, the inability to install drainage and the speed of installation. The speed of installation depends on the type of concrete support they can be solid and teams. Solid is not allowed to collect roof supports in the mines, unlike teams. But there is a need to
improve this type of support by installing a drainage system that allows you to remove water from the production to the surface directly through the mountain support, without the possibility of heating the concrete base [7-10]. In other words, the presented design solves the issues of water withdrawal, without the use of pumping units in the mine itself, and without harming the concrete structure with water.[11] To consider the design of the mountain support, it is necessary to give a description of the effect of Leidenfrost, on which this improved, reinforced concrete support is based.

2. Leidenfrost’s effect

2.1. Researches and results
Leidenfrost’s effect was founded as a result of putting liquid on a heated surface. The result of this action had three events:

1) If the temperature is lower than 100 °C, liquid spreads on heated surface and gradually evaporates

2) If the temperature is 100 °C and higher, liquid evaporates much faster with hiss.

3) Liquid’s drops begin to form small in diameter ball’s, when it reach Leidenfrost’s point. These balls start moving on a heated surface.

So Leidenfrost’s effect - is a phenomenon when liquid contacting with physical body that has temperature bigger than this liquid’s boiling point and making an isolating vapor layer, that saves water from fast evaporating. Graph of temperature versus time of liquid evaporation is showed on a Figure 1.

![Figure 1. Graph of temperature versus time of liquid evaporation.](image)

Essence of the effect is the following: when the drop is putted on plate, heated to Leidenfrost’s point temperature, it will evaporating gradually. It’s connected with vapor formation of drop as a result of contact of drop and heated plate.

2.2. Reasons of liquid movement
The duration of the droplet evaporation time is related to the fact that the vapor is a poor conductor of heat, so the lower part of the liquid will constantly evaporate forming a vapor layer, thereby contributing to raising the drop above the plate. Scientists founded that the movement of a drop depends on the following physical phenomena:
1) The inhomogeneity of the radius of a drop curvature generates a Laplace pressure gradient.

2) Inside the drop, there are processes of transfer of matter from the back part to the front, which generate motion.

3) Due to the inhomogeneous thickness of the vapor layer, oscillations, which can be converted into kinetic energy of directed motion, appear.

4) The Margosha effect consists in the fact that drops, located on the surface of a liquid with an inhomogeneous distribution of the surface tension coefficient, begin to shift to the region where the value of this quantity has a maximum.

However, there is another reason that explains the movement of solids, as well as liquid bodies, based not on their liquid nature like the four above-described reasons. For this, should be given an example of the displacement of a solid body capable to pass from a solid state to a liquid phase, and then to a gaseous state. For example, carbon dioxide (Figure 2) can be put on a hot corrugated plate. After that, the plates begin to move. The essence of this reason is as follows: on an even surface the Leidenfrost drop’s vapor oozing out uniformly and isotropic under the drop. However, with a corrugated surface, the steam flow becomes anisotropic and a certain direction appears, which allows you to move the droplets not only in the vertical direction (angle = 0°) but also upwards (an angle of more than 0°).

![Figure 2. The movement of carbon dioxide.](image)

3. **Leidenfrost’s effect**

Now let’s proceed directly to the application of the Leidenfrost’s effect in mining. The Leidenfrost’s effect has a great importance for mining. Usually using in mining pumps, thanks to the construction presented in this article it, can be removed from underground structures, since the pumps are rather cumbersome, energy-consuming and work intermittently, that’s why three pumps are being used in one section of the mine at the same time. Therefore, the method of water intake using pumps is very impractical. In this development, it is proposed to use drains with built-in corrugated metal plates, which will be heated to 130 °C, supplying liquid to the reinforced concrete support. There are the plate, that heats the water up to the aggregate state of steam, which then rises along the reinforced concrete structure[10], the pipe is 3 cm in diameter and 2 cm in thickness, which allows to carry up to 10 liters steam per minute, and the thickness allows to withstand up to 2200 MPa of rock pressure [13]
As iron, it is proposed to use chrome-plated steels with a martensitic structure, because of the high resistance to pressure and anti-corrosion properties, the concrete will promote the safe advance of the steam before exiting from the mine workings, and also provide increased toughness. But in this design there are some problems:

1. High pressures can form a crack in the concrete.
2. Seismic movements of the earth layers may damage the support.

But these problems can be solved with the help of methods and algorithms developed in the Institute of the SB RAS for modeling the process of redistribution of stresses in rock massifs and lining taking into account progressive mining operations.[10-14] The methods and algorithms of which are based on the use of the initial stress and deformation methods, which imply the application of the rigidity matrix of the calculation, which does not undergo changes in the determination of nonlinear solutions [13-15].

The time of heat up calculated by the formula 1

$$ P \cdot t = C_w \cdot m_w \cdot (100^\circ C - T_1) + L \cdot m_w + C_v \cdot m_w \cdot (T_2 - 100^\circ C) $$

**Formula 1** The time of heat up.

Where $P$ - power, $t$ - time of heating, $C_w$ - specific heat capacity of water, $m_w$ - mass of water, $T_1$ - the initial temperature of the water, $L$ - specific heat of vaporization, $C_v$ - specific heat capacity of vapor, $T_2$ - final temperature of water.

As a material, used to create corrugated plates, it is proposed to use an 1 cm thick lead coating that can suppress the negative effects of radioactive minerals contained in groundwater. It is also proposed to apply lead with a metals, that will suppress groundwater’s negative properties, depending on the toxic elements contained in it. The device of the construction is shown on Figures 3-5.

![Figure 3](image-url) view of the structure from above.
Figure 3 shows a view of the structure from above. It allows consider the average width of the structure, regardless of various geological and physical parameters. Width as well as other dimensions can vary depending on the set parameters.

![Figure 4 View from the front.](image)

Figure 4 shows a view from the front, which allows see the pipes, through which the steam will flow. The height of this construction will depend on the given geological and physical parameters.

![Figure 5 View from the flank.](image)
Figure 5 shows a structure depicted from the flank.

This construction is energy-consuming, but there is a solution for using steam. Steam, rising on the supports of the mine workings, is taken out to the steam generator, which generates a part of the energy expended on the power of this installation. As a result, using the formula, we can determine that the efficiency of the steam generator will be equal to 60% and the steam generator will allocate about 30% of the energy, expended for the entire plant. This can be seen from the following formula 2

\[ \eta = \frac{E}{P \times t} \]

**Formula 2** Calculation coefficient of efficiency.
Where \( \eta \) is efficiency coefficient, \( E \) is useful energy, \( P \) is power, \( t \) is time of heat.

4. Conclusion
Improving the support of this type facilitates a number of tasks related to the efficiency of the speed and safety of mining in closed, combined and dredging ways. It helps to more effectively eliminate water from the mine workings of closed, combined and dredging type, allowing it to be used as an energy source, thereby providing mining production of some amount of electricity. It eliminates the need for pumping plants in mining. It is worth noting that this improvement in addition to its technical qualities has an economic advantage due to the repeated use of improved mountain support, that is, there is a possibility in multiple Assembly and disassembly of this improved support. Therefore, we can conclude that this improved support has a huge number of advantages, which consists not only of the advantages taken from its earlier version, but also its unique advantages derived from the eliminated disadvantages of the previous version.

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