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Modelling of Aerodynamic Process for Coal Waste Dump Located in Geodynamically Dangerous Zone

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Modelling of Aerodynamic Process for Coal Waste Dump Located in Geodynamically Dangerous Zone

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Abstract. Previously made evaluations show confinement of fire coal waste dumps to geodynamically dangerous zones which in this work are considered as borders of active blocks of the earth crust. According to the hypothesis under development, when disposing the dumps in geodynamically dangerous zones (GDZ), which have a high penetrating, aerodynamic relation of the dumps with the environment occurs, xmaking the dumps firing possible. Firing of the dumps inflicts environmental, social and material damage. This research is aimed to study possible mechanism of gas mass transfer through GDZ into the body of dump on the base of computer modeling of aerodynamic processes. A relevant geometry model is developed, borderline conditions are proven and modeling of aerodynamic process is shown in the work. Taking into account actual data on location and characteristics of firing dumps of a region of Eastern Donbas (Rostov region, Russia) calculation are performed by means of ANSYS software. A dump located in GDZ is modeled. The GDZ is set in the model as a highly penetrating linear zone in the rock, which has a deep emplacement. The GDZ crosses mine fields and has an expression in relief of the Earth surface. Temperature of the rock within the dump may reach 420 degrees Centigrade. Petrophysical characteristics are taken into account in the model (porousness and permeability) of its main structural elements, dimensions of the dump, width of GDZ, difference of relief heights, depth of mine workings location under the dump. The results of the modeling show influence of the dump temperature, petrophysical characteristics of the model structural elements, depth of the mine openings location on aerodynamic processes within the dump mass. Operability of the model at the preset border conditions allows to deeply argue the hypothesis of the air intake into the dump body with consideration of the local geodynamics. According to the results obtained, geodynamic conditions of mining area where coal waste dumps are disposed, may be and are an important factor, which has an effect on creation conditions for spontaneous combustion of dumps and its further impact on environment.

1. Introduction

Spontaneous combustion of coal waste dumps is an actual ecological problem worldwide in mining areas of many countries involved in coal mining: Russia, Poland, South Africa, China, Germany, etc. [1-5]. Burning dumps cause ecological, social damage and damage to property.

One of possible causes of spontaneous combustion is air inflow into dump body that initiates exothermic oxidation reactions in the coal substance. Despite significant progress in this problem solving, the issue of spontaneous combustion of dumps remains relevant and this indicates that there is still an unaccounted factor that creates conditions for self-ignition.

In this regard, a hypothesis is proposed that spontaneous combustion of dumps is associated with their location in geodynamically dangerous zones of the earth's crust. Due to high permeability of such zones, connection of waste dumps with the environment occurs [6].

The purpose of this paper is to study a possible mechanism of mass transfer of gases via a geodynamically dangerous zone into the dump body based on computer simulation of aerodynamic processes. A corresponding geometric model is developed in the paper; with the boundary and initial conditions justified and simulations of the aerodynamic process made using the ANSYS software, which has proved itself as a tool for solving aerogaseous and dynamic problems [7-9].

2. Geodynamic position of the "Nesvetaevskaya" mine dump

The coal-bearing dump of Nesvetaevskaya mine is located near the town of Novoshakhtinsk, the Rostov region. The dump has a base area of 154 500 m^2 and a volume of 2 940 000 m^3. A large part of the dump is reclaimed, but with no trees planted. In the northern part, the dump looks like a flattened cone with a maximum height of 27 m. The southern part consists of four combined peaks with a maximum height of 39 m. The dump is burning and is classified as "very dangerous". A secondary use of mine openings is planned in this area [10].

The block structure of the rock massif in this region was studied by the method of geodynamic zoning [11]. Studies have shown that the dump is located directly on the border 3rd rank blocks, the Nesvetaevsky fault (Figure 1). The Nesvetaevsky fault is strikes to northwest and affects the modern surface relief.

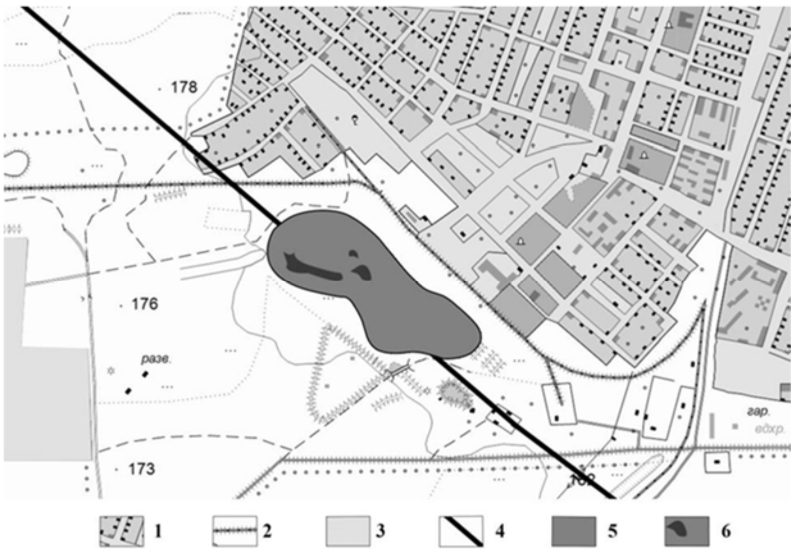

Figure 1. Location of the united mine dump Nesvetaevskaya: 1 - residential zone, 2 - roads, 3 - forest, 4 - Nesvetaevsky fault, 5 - Nesvetaevsky dump, 6 - burning spots

This fault has an independent route, varying from the routes of major known tectonic faults in the region, and taking a cross-cutting position to them. Its appearance and functioning in the modern stress field can be explained by modern redevelopment of the structural plan of the entire Donbass region, which is noted by many scholars, for example, in [12]. Based on available research results for two mine fields in Donetsk, the Nesvetaevsky fault can be assumed to be expressed as an area of increased fracturing in the massif. The width of the area of increased fracturing, i.e., the width of the geodynamically dangerous zone created by this fault is 50 m, and is estimated by the following formula [13]:

$$B = 10 \cdot N, \tag{1}$$

where N – is the displacement amplitude.

According to a temperature survey, the combustion sites on the dump have a linear shape, some of them extended towards the Nesvetaevsky fault. The total area of combustion sources with temperature from 80 to 434 ºC reaches 13 000 m^2, which over 8% of the total area of the dump. In addition, the results of the temperature survey of the coal dump have shown areas with anomalous temperature of 40-80 °C, which indicates the continuing process of autonomous heating of the dump mass and the emergence of new sources of ignition.

3. Results and discussions

3.1 Model of air filtration through the dump

There are works available focused on simulation of air motion in the dump area [14, 15], but our model is characterized by considering a permeable geodynamical dangerous zone, with a pronounced relief ledge in the surface. The ledge is 20 m high. The simulation showed that the air moving to the relief ledge penetrates the rock massif by several meters, and then leaves to the atmosphere, as shown in Figure 2 (a), 2 (b). The same situation occurs when the air flow directly runs onto the dump (Figure 2 (c), (d)).

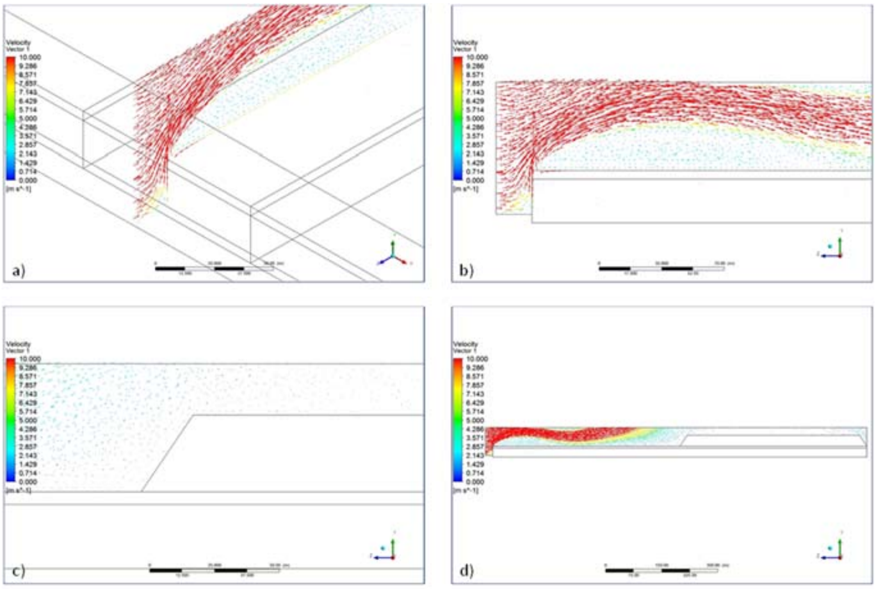

Figure 2. The air motion vectors in the cross section of geodynamically dangerous zone: a) in the atmosphere and in the rock (isometry, a section of the ledge is approximated), b) in the atmosphere and in the rock massif (side view, the ledge area is approximated), c) in the atmosphere and in the dump (side view, from the incoming air flow), d) a general side view

There was also simulated a situation when the dump is located near the mining area and is associated geodynamically by dangerous zone with the mine atmosphere, Figure 3. In such case the air pressure in mine openings may be taken as 1000 Pa.

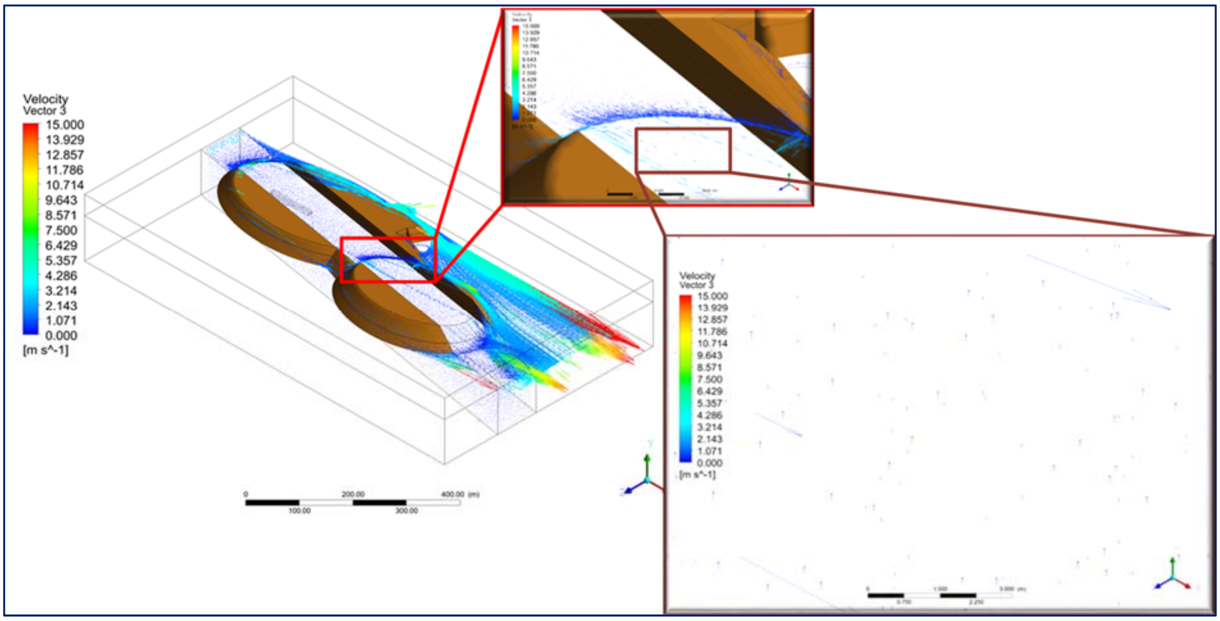

Figure 3. The air motion vectors when the dump and the mine atmosphere are connected via the geodynamically hazardous zone

It can be seen from Figure 3 that air moves upward from the lower surface of the geodynamically hazardous zone due to excess pressure. Air passes through the dump and enters the atmosphere. The air motion is visualized by vectors of different colours, depending on its velocity.

3.2 Model of gas filtration through the dump in case of elevated temperature

At the second stage, there was simulated a situation of a source of elevated temperature available in the dump. Additional favourable conditions for the mass transfer of gases were assumed to be created due to the fact that the combustion site acts as an additional source of draft.

A geometrical model of a dump of Nesvetaevskaya mine was developed with initial and boundary conditions given. The temperature of the horizontal surface in the dump was taken as a variable parameter (Figure 4). The simulation was provided for 100 °C, 200 °C and 400 °C.

The simulation showed that a temperature gradient field forms above a hot surface in the dump body, if such forms (Figure 5). Due to the temperature difference, upward air flow currents are formed above the surface (Figure 6a, b, c, d). The ascending air currents in their turn create additional favourable conditions for a transfer of gas masses inside the dump, Figure 7 a, b, c, d.

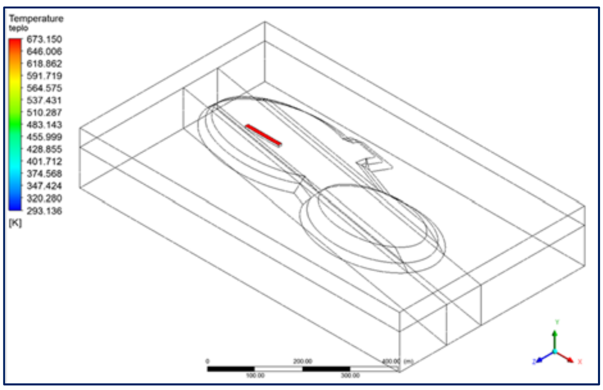

Figure 4. Geometrical model of the dump of Nesvetaevskaya mine with a surface of elevated temperature

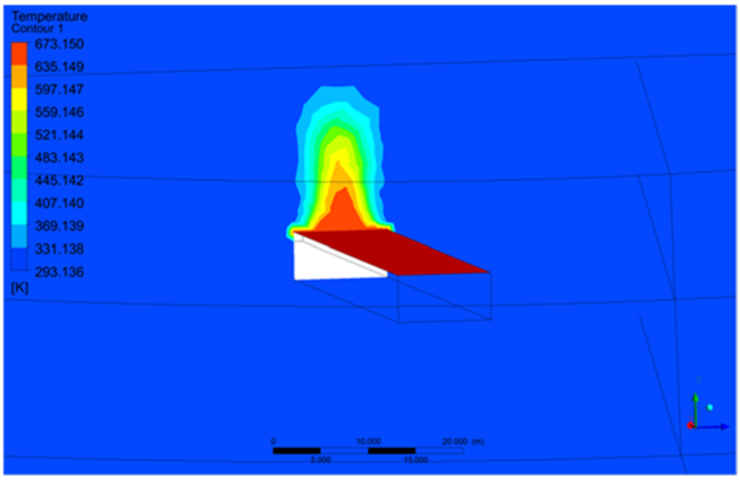

Figure 5. Temperature gradient over the surface with elevated temperature of 400 °C

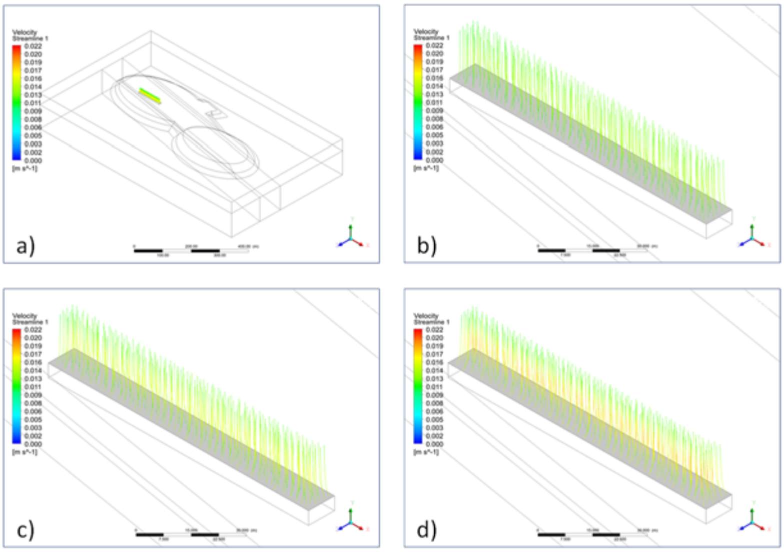

Figure 6. Air currents over the surface with elevated temperature a) general view, b) 100 °C, c) 200 °C, d) 400 °C

Figure 6 shows that the air currents are directed upward from the heated surface. Air travel paths are colored according to their velocity in each of the sections. For visualization, a speed range from 0m/s to 0.22 m/s was chosen. When comparing Figures 6b, 6c, 6d, an increase in velocity in the central part of the path can be observed, depending on the temperature of the heated surface.

Figure 7a shows the position of the model cross section, and Figure 7b, 7c and 7d - the air motion vectors in the cross section plane.

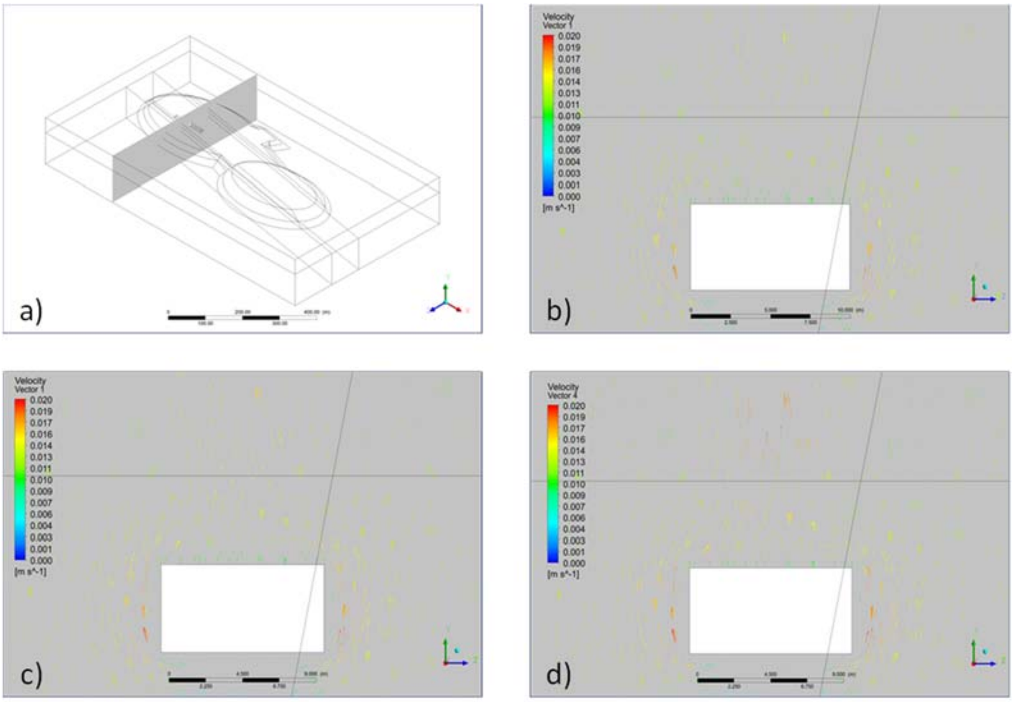

Figure 7. The air motion vectors in the cross section over the surface with elevated temperature: a) general view, b) 100 ºC, c) 200 ºC, d) 400 ºC

Figure 7b, 7c, 7d show that the velocity of the air-gas mixture is affected by both the aerodynamic resistance (when moving along obstacles) and the temperature change. As the temperature of the heated surface increases, so does the air velocity the dump in the impact area of the combustion source.

When methane-air mixture passes through locations with a temperature of 100-400 °C, there occur favorable conditions for an increase of both the temperature and the combustion area. With the surface temperature growth, the air motion velocity over this surface also increases.

4. Conclusions

The results of the entire simulation process confirm the hypothesis that the geodynamic conditions of the dump location act as an important factor affecting its endogenous fire hazard. Using a computer model that simulates the real parameters of one of the burning coal-bearing dumps, it is shown that:

- when the coal-bearing dump is located on a high permeable zone connected with reduced relief areas or a mine, some favorable conditions may be created for the gases to enter the dump body from either the surface and the mine;
- if a source of ignition occurs and the temperature rises, it additionally contributes to gaseous mass transfer from an environment in the dump body and can lead to increase in the combustion intensity and area. As the temperature of the ignition source increases, the air velocity within the dump increases as well.

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