

Fissuring due to Inundation of Coal Mines and Its Hydrodynamic Implications

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Inundation of coal mines can be accompanied by unexpected water inflow and inrush to mine workings of neighboring coal-producing enterprises. In this case, it is common for mine water to inflow through barrier and shaft pillars that are waterproof during exploitation.

Such cases are beyond the scope of researchers, and no scientific explanation for them has been provided. This work considers data on water overflows and causes for their appearance in such situations.

The fact of water overflow reflects variations in the permeability of carbonaceous rocks and sediments near the newly formed water pools.

These processes are demonstrated by events in mine workings of the Zapadnaya Mine (eastern Donbas region) recorded during water inrush in February and October 2003. The latter event received wide coverage in the mass media.

Both water inrushes originated far from mining operation areas and were unrelated to production activity therein.

In the first case, water rushed into the block ventilating shaft no. 1 from nearby inundated workings of old mines at the bottom of a major syncline.

At the initial visually controlled stage, the water rushed through a suddenly formed and episodically widening (over about a month) fissure in a monolithic concrete support and the shaft wall. According to mine service data, water discharge increased gradually and reached 30 000 m³/h in the daytime on February 3. The growth of water inflow rapidly gave way to its significant attenuation without any explicit relation to the filling of the shaft with rock materials in order to control the inrush. Water inflow often changed in a spasmodic manner: intensification and attenuation alternated at the

controlled stage of water flow loss. Upon cessation of shaft filling, a decrease in water inflow continued and proceeded in the stepwise regime. For example, the discharge was 50 m³/h from February 10 to March 2; 38 m³/h from March 3 to June 1; and 26 m³/h from June 2 to October 4, 2003 (Fig. 1). Under conditions of a succession of slight decrease and increase in the inundation level in old mines, such an inflow regime can be accounted for in the dynamics of the fissure channel opening.

The genetic relationships between the fissure cavity formation and the existence of a water pool in workings of neighbor mines are confirmed by the extent of fissuring in similar situations and other hydrodynamic events in the Zapadnaya Mine, in particular, the conditions of water inrush to the main vertical shaft no. 2 on October 23, 2003.

Like the previous inrush, the latter event is related to water inrush from inundated workings located near shafts of the same mines.

The inrush was sudden without any obvious and common forerunners. Examination of the shaft lining five hours before the inrush did not reveal any significant and new water flows or channels ready for large-scale water inrush. The discharge reached 50 000 m³/h in just a few tens of seconds after the inrush onset.

The site and channel of direct water inflow into the shaft remain unknown. However, indirect data allow us to reliably classify the channel as a newly formed fissure-type cavity and explain its emergence by inundation of neighbor mines.

Observations revealed irregular rates of the Zapadnaya Mine inundation. Figure 2 illustrates the dynamics of water level growth between adjacent measurements with 1- and 2-h intervals. During some intervals, the inundation level retained invariable and reflected a small, nearly background water inflow (500–1000 m³/h). Inside the mine, periodic surges of mine water from the shaft and powerful shakings of the massif (“blows” according to miners) were recorded. They were followed by

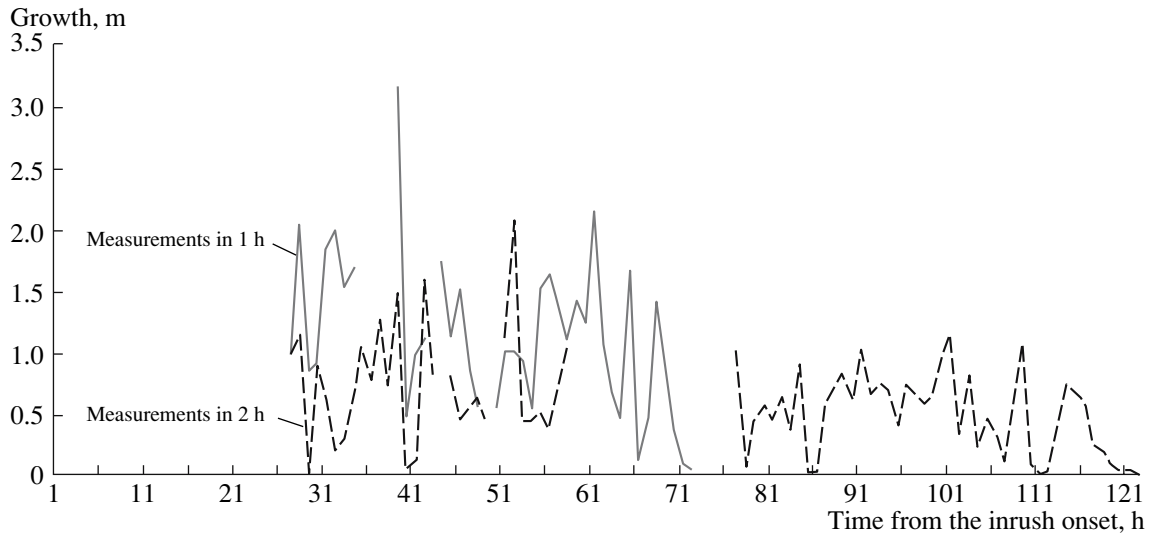


Fig. 1. Growth of the level of the Zapadnaya Mine inundation compared to previous measurements during water inrush to main shaft no. 2.

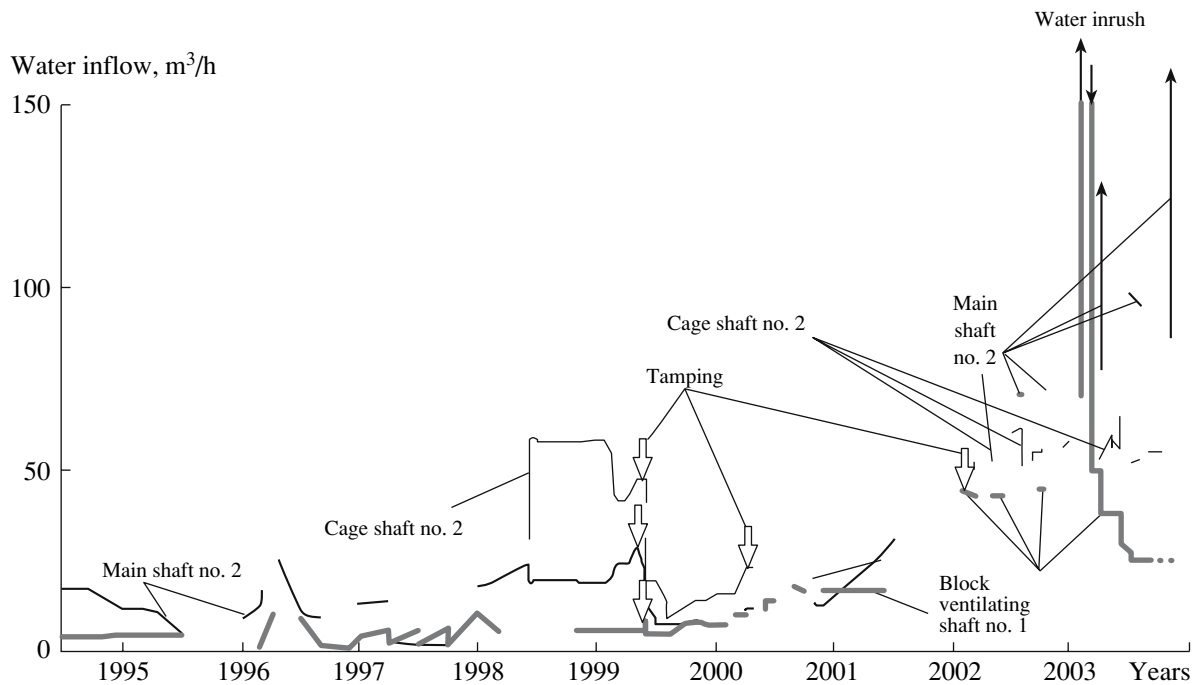


Fig. 2. Dynamics of water inflow to shafts of the Zapadnaya Mine.

new water flows and an increase in the rate of mine inundation.

These effects were recorded prior to and in the course of filling of the shaft with rock materials, testifying to variations in the water discharge and periodic cessation and resumption of the inflow of a substantial volume of water due to natural processes.

It may be inferred that the inrush represented a series of water inflow, the dynamics of which was recorded by the effects mentioned above. We should

rule out the possibility of the pulsation of water discharge due to a periodic colmatage (silting) of the water channel, because the hydrostatic pressure on the possible discharge source is very high (about 1.8 MPa) and the calculated rate of water inflow to the shaft is significant (tens of meters per second).

Sharp variations in inflow up to the point of its cessation and instantaneous attainment of the inflow maximum suggest that water rushed through an episodically forming, narrowing, and even closing channel (or a series of channels) in the shaft wall. In some cases, the

channel formed and, probably, reopened for tens of seconds. The inflow plot (Fig. 2) shows that the channel could remain in the open state over a period of several minutes to several hours. In our opinion, such properties can be related to the fissure-type cavities, which have the capacity of potential reversible opening. Our calculations show that the fissure opening exceeded 10 cm. The validity of this inference is confirmed indirectly by data on water inrush to the block ventilating shaft no. 1 in February 2003.

It should be noted that both inrushes were characterized by comparable maximal discharge and stepwise fluctuations followed by significant attenuation of inflow unrelated to the shaft backfilling. The characteristics and conditions of water inflow suggest that it was generated by cyclic variations in the stressed state of the rock massif due to natural causes.

Effects of such fissuring also took place before and after both inrushes.

The records show signs of both abrupt and gradual generation, opening, and narrowing of water-conducting fissures during the formation of a water pool in the course of inundation of old mines. It was accompanied by the growth of water inflow to shafts of the Zapadnaya Mine. This process was slightly slowed down by cementation of space near the shaft (Fig. 1). In main shaft no. 2, episodic water seepage and jets were observed during the driving of sandstones in the interval of old mine inundation. Variation in the inflow to different shafts was asynchronous and proceeded in a discontinuous manner with short-term recessions.

Diagrams of water inflow to shafts (Figs. 1, 2) demonstrate that pulsation of its discharge was characterized by different grades.

The impulse of fissure formation could be responsible for a sharp increase in water inflow to cage shaft no. 2 located 150 m away from main shaft no. 2 in 1998. At the same place, a sudden seepage of water of unusual appearance was recorded on October 2003 just before the inrush to main shaft no. 2. Signs of substantial water inflow in the course of inrush were also recorded.

The water inrush to the air pit in June 2001 through the borehole could have been provoked by one of the impulses of rock massif unconsolidation because of a sudden failure of the casing at its intersection with an inundated goaf. Extension of the fissure to the shaft was not recorded there.

Wide tensile cracks appear in some places episodically and suddenly on the surface of inundated mines in the study region. Indirect signs of spontaneous and transient fissuring were registered. For example, a sudden drainage of water well drilled to capture an aquiferous horizon of coal seams above the inundated space was recorded in December 2003. The water returned to the well after three months.

The appearance of fissures can be explained by the well-known impact of Archimedean forces generated by water saturation of the rock massif. Such an impulse of fissure opening took place in the rock massif of the Zapadnaya Mine due to the formation of a major water pool.

The suddenness of water inrush, pulsations of water discharge and water pools, and quakes of the rock massif indicate that the gradual unconsolidation of rocks can give way to their jumpwise decompaction with expansion of cavities and formation of new cavities as a manifestation of the capacity of rocks to abruptly release elastic energy of compression during the energy relaxation.

Similar processes are manifested in unloaded rock specimens, especially in sandstones, in the form of their cracking, for instance, during the "disking" of the core of explosive rock varieties.

The fissures can also close in a similar spasmodic manner at some moments.

The pulsation of water inflow indicates fluctuations in the cavity-forming process triggered by Archimedean forces in a medium.

The stability of water inflow to main shaft no. 2 and cage shaft no. 2 during water inrush to block ventilating shaft no. 1 and the asynchronism of intense water flows into different shafts and rock massif sections indicate the local nature of fracturing. These peculiar features of hydrodynamic events serve as a sign of the migration of decompression fissures along bedding planes, probably from the deepest inundated part of the mining system and the syncline bottom to the Earth's surface. According to indirect data, the probable length of fissures in plan view did not exceed 100 m.

Thus, inundation of mines transforms the filtration structure and permeability of rocks. Relaxation of internal stresses in the massif gives rise to autooscillations that can provoke local destruction of its entirety and generate hydraulic pulses with breakthrough of water into mine workings.