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# Innovative technologies for thick coal seam mining on the basis of powered roof support with controlled coal discharge

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# Innovative technologies for thick coal seam mining on the basis of powered roof support with controlled coal discharge

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**Abstract**. A new trend for designing powered supports for thick coal seam mining with controlled coal discharge is substantiated. Numerical modeling for gravity flow of disintegrated rocks and the flow interaction with the support section is performed. A test bench is developed, and the laboratory studies into coal discharge process are carried out.

## 1. Introduction

New technologies for mining thick flat and steep coal seams use use force of rock pressure for physical destruction of coal, which needs machines with extra capabilities. Many countries investigate and justify mining technologies for thick coal seams with discharge of softened top coal [1–6]. The new proposed design of a powered roof support equipped with controlled coal discharge to armored face conveyor possesses advantages and eliminates drawbacks of the known analogs (Figure 1) [7, 8].


**Figure 1.** (a) Longwall top coal caving technology in mining thick flat coal seams; (b) general view of powered roof support with controlled discharge of caved coal to armored face conveyor.

In this regard, it is important study the process of caved coal discharge. One of the most popular methods used to model deformation of geomaterials is the method of discrete element (DEM) for the first time put forward in [9]. This method allows determining stress state evolution in broken rock mass both at pre-limiting stage of loading and in transition to shearing localization and failure. At the present time, DEMe enjoys wide application in solving geomechanical problems [10–12]. In DEM a real medium is replaced by a set of discrete particles with the assigned laws of interaction between them. This method faces no difficulties in solution of problems with high (finite) deformations and rotations. Thus, DEM is a principal alternative to classical methods based on conventional concepts of continuum mechanics. In the framework of DEM, gravity flow of coal discharge to AFC via feeder was modeled numerically [13].

## 2. Numerical and laboratory modeling

The experimental design is depicted in Figure 3. The figures marks the model elements of the powered roof support unit: capping *1* with a length of 2.5 m; immobile vertical gate *2* with a height of 1.75 m to limit velocity and volume of granular material flow; feeder *3* with a length of 3.575 m inclined at 12° to horizontal plane; discharge opening *4* with a width of 2 m, shut at the stage of initial flow configuration formation; side shields *5* spaced at 1 m.

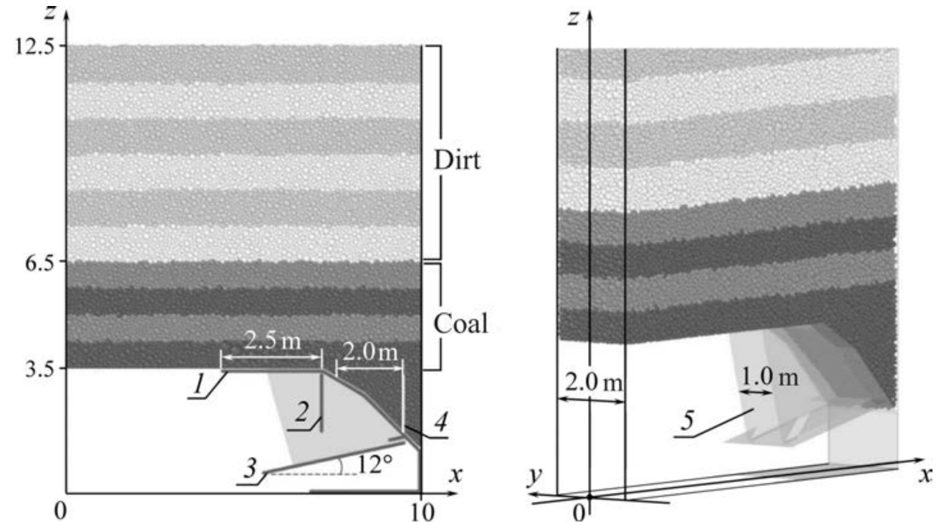


**Figure 2.** Experimental design.

The influence of the feeder design on the flow behavior was studied in two tests. In the first test, the feeder surface was smooth, and in the second test, it was corrugated with step plates 1.15 long arranged in parallel to horizon plane. The inclination of the feeder was 12° in both tests. When broken rock mass reached equilibrium, the discharge opening was opened and the material started flowing unit the next equilibrium state was reached owing to the vertical gate after the feeder was deactivated. The pressures of the flow on the gate and on the feeder, $P_d$ and $P_f$, respectively, were recorded and plotted (Figure 3)

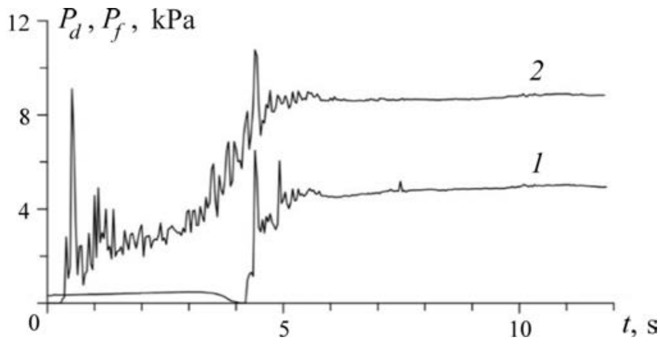


**Figure 3.** Pressure of granular material flow on the gate (*1*) and deactivated feeder (*2*).

The actuated feeder, due to contact friction between the particles and the particles and the feeder, makes the material move. The broken material flow reaches steady state in some time. The mass flow rate of coal, $M_c$, in this mode within 45 s is described in Figure 4. With the smooth feeder, $M_c$ is 47 kg/s at the total discharged coal mass of 2193 kg (Figure 4a). With the corrugated feeder, these indexes are 32 kg/s and 1500 kg, respectively (Figure 4b).

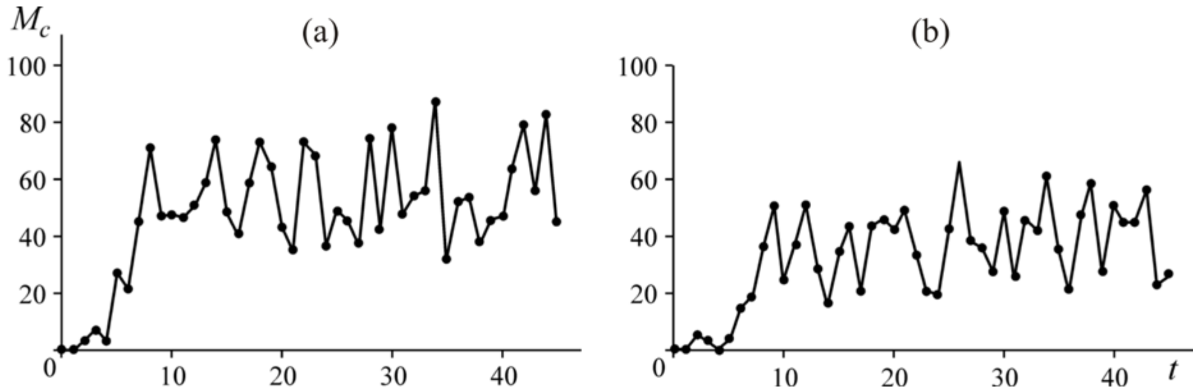


**Figure 4.** Mass flow rate of coal with (a) smooth and (b) corrugated feeder.

Twenty models of powered roof support units with advancing facilities were manufactured for the tests (Figure 5). The total length of the model units was equal to the inner width of the transparent testing box (1600 mm) (Figure 6). Discharged coal is transported from the face zone by a belt 65 mm wide and 4 mm thick, mounted in front of the base frame of the laboratory test installation. The belt is driven by a gear motor arranged under the test bench. The belt capacity is adjusted using a frequency converter. The tension of the belt is executed by a tensioner mounted on the opposite side of the testig box and composed of a tension drum and tightening screws.

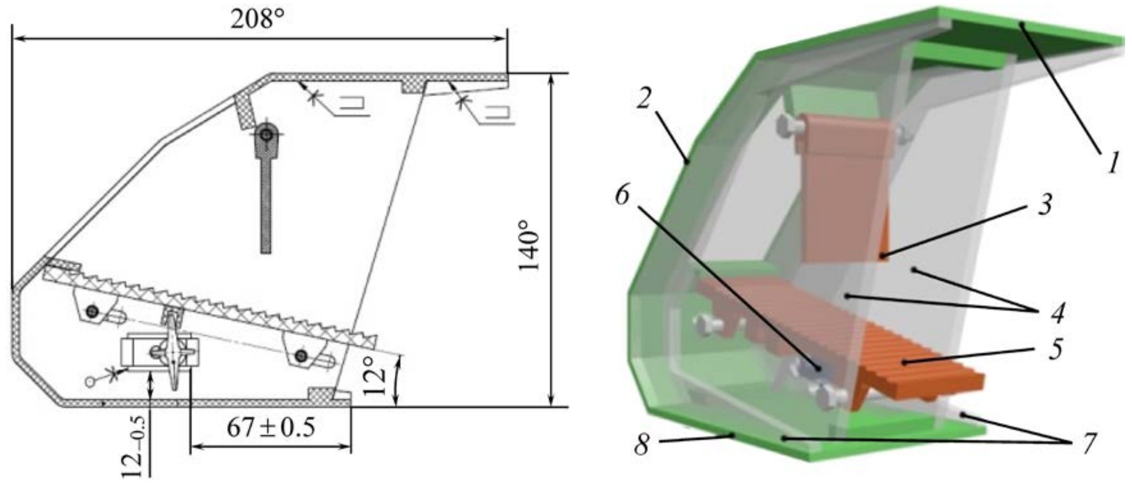


**Figure 5.** Powered roof support unit (sketch and model): *1*—capping; *2*—goaf shield; *3*—gate; *4*—inner enclosure walls; *5*—automatic discharge facility (feeder); *6*—servomotor of feeder; *7*—external side walls; *8*—understructure.

**Figure 6.** Laboratory test bench.

The control system of the discharge flow includes instrumentation and software making it possible to vary feeder parameters (frequency, amplitude) and operating modes of roof support units (individual, grouped). The test bench is also equipped with photo and video recording devices.

This test bench allows experimentation on coal discharge from the powered roof support units operating in various regimes: individual and grouped, wavy and full-length.

Coal is simulated by gravel painted black, faction 5–15 mm; dirt is modeled by grey-pinky marble chips 13–15 in size. For better visualization of flow process, coal layer is parted by a layer of white gravel particles 5–10 mm in size (Figure 7).

**Figure 7.** Laboratory testing of discharge flow in different operating modes.

## 3. Conclusions

1. The presented DEM-based model of gravity flow of broken rock mass in the longwall top coal caving technology includes all process stages: creation of initial equilibrium state of rock mass; discharge of mineral to feeder of powered roof support unit; operation of the feeder and material discharge in accord with the process chart of the support.
2. The cyclic operation of the feeder is the cause of the cyclic change both in the mineral flow and in the load imposed by the flow to the elements of the powered roof support unit during discharge. The configuration of the feeder surface has considerable influence on the process parameters under analysis.
3. The developed model of the powered roof support unit is equipped with the discharge control system composed of instrumentation and software making it possible to vary the feeder parameters (frequency, amplitude) and the unit operation mode )individual, grouped). The designed test bench is fitted with photo and video recording devices. The tests of the discharge flow process on the test bench shows conformance between theoretical knowledge and experimental results.

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